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EVALUATION OF SOILS AND USE OF SOIL SURVEYS FOR ENGINEERING PURPOSES IN URBAN DEVELOPMENT

A Technical Studies Program Publication

FEDERAL HOUSING ADMINISTRATION
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THE FEDERAL HOUSING ADMINISTRATION
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EVALUATION OF SOILS AND USE OF SOIL SURVEYS FOR ENGINEERING PURPOSES IN URBAN DEVELOPMENT

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This publication presents the results of research done under the Technical Studies Program by the Virginia Polytechnic Institute and does not represent FHA standards.

FOREWORD

A large portion of the United States has been covered by national soil surveys. The judicious application of these to engineering purposes would make it possible to obtain greater economy and efficiency in all soil aspects of residential construction. However, the soil surveys have not been prepared specifically for engineering purposes and, therefore, require interpretation for optimum utilization. Accordingly, the Federal Housing Administration has developed this publication as a guide to converting basic agricultural research for engineering uses.

Philip N. Brownstein

Philip N. Brownstein
Commissioner
Federal Housing Administration

Much of the United States has been covered by a national soil survey which was done by the Department of Agriculture. The skillful application of this information to many engineering problems makes it possible to obtain greater economy and efficiency in the handling of all soil engineering problems concerned with residential construction. To aid in this application, the FHA Technical Studies Program has prepared the attached publication, FHA No. 723, "Evaluation of Soils and Use of Soil Surveys for Engineering Purposes in Urban Development," which will provide guidance for more specific use and interpretation of the existing soil survey reports.

In conjunction with existing soil survey data, this publication can be used effectively as a guide for the evaluation and processing of properties by anyone concerned with technical phases of housing development. Its use can significantly reduce the need for more complete laboratory analyses or field tests.

This does not constitute an FHA standard.

A limited supply of FHA No. 723 is available. Additional single copies may be obtained without charge from the Office of Public Information, Federal Housing Administration, 811 Vermont Avenue, N. W., Washington, D. C. 20411. It is anticipated that in the near future multiple orders will be filled by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

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PREFACE

Many engineering problems associated with intensive land use for urban development originate with soils in their natural state. The use of properly interpreted soil survey data has proved to be an effective tool in the solution to some of these problems.

The outstanding usefulness of soils information to crop production has been the impetus of half a century of agricultural soil surveying. Still, scientists have insisted that classification and soil survey mapping units be based on genetic soil properties rather than on agricultural capability. They envisioned that soil maps and reports of a basic rather than a specialized nature would prove useful for many purposes other than agriculture. This has materialized.

Recent redefinition of engineering soil classification and increased awareness of the significance of natural soil variations have stimulated the widespread use of applied soil science, including soil surveys, to many engineering problems associated with urban development.

The volume of literature concerning the engineering applications of pedologic concepts has also grown rapidly. In addition, specific design recommendations based in part on such concepts are now being made daily in the field. Engineers are engaged in the study of survey reports and maps, mapping units, and regional soil correlations. Advantages are being realized in tangible savings as well as in homeowner satisfaction and community welfare.

The Government also has an interest in this field. In 1960, the Technical Studies Staff of the Federal Housing Administration amended a contract with the Virginia Polytechnic Institute in which FHA had originally requested soil classification information. The amendment called for development of criteria and procedures for judging soil survey mapping units for specific engineering uses.

This publication incorporates the criteria and procedures developed under this contract in the evaluation of soil survey series and mapping units in four selected counties representing significant soil regions throughout the eastern part of the United States. It provides specific criteria for judging and rating the soils for individual sewage disposal systems and for other engineering uses. The soils which were studied were mapped by the Department of Agriculture and cooperating states in a national soil survey program.

In order to establish and demonstrate fully the scope and usefulness of this study, it was necessary that the experiences encountered and judgments made in the evaluation of the soils in the four selected

representative counties be documented. Accordingly, related data in the form of separate engineering maps have been processed and assembled as supplementary information which illustrates by color and cartographic symbol the various soil ratings for engineering uses. These supplementary data can be purchased directly from the Engineering Experiment Station of the Virginia Polytechnic Institute.

The basic data comprising the report were developed at the Virginia Polytechnic Institute by R.D. Krebs and J.H. Hunter, Associate Professors of Civil Engineering. Dr. W.A. Parsons, Professor of Civil Engineering, served as advisor on the general sanitary engineering features of the study. It was prepared under the administrative direction of Professor H.M. Morris, Head of the Civil Engineering Department. This publication presents the results of research done under the FHA Technical Studies Program.

James R. Simpson, Bernard T. Craun, and Elvin F. Henry of the Federal Housing Administration, Architectural Standards Division, Technical Studies Staff directed and managed the development of these data in the field and assembled them for publication. Mrs. Mary C. Dragoo edited the report and prepared it in its final form.

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The widespread conversion of rural areas to urban and suburban developments in recent years has necessitated the use of single unit sewage disposal systems. These systems, which are associated with single or small multiple living units, are referred to as residential sewage disposal systems in this publication.

The suitability or acceptability of a residential sewage disposal system depends upon the design of the system and the ability of the soil to absorb the effluent. Design and construction modifications can be made compatible with some soil variations. Design modification, however, is severely hampered in most instances by limitations of cost, space, and knowledge. Also, both the inherent characteristics of soils and their significance are often disregarded, which leads to widespread misinterpretation and erroneous predictions concerning soil suitability for individual sewage absorption systems. As a result, there have been a large number of individual disposal system failures and soil conditions for which no known design is completely appropriate.

In this report, the design factors concerning the quantity of sewage or the quality of treatment provided by the septic tanks are not covered. Rather, soil is considered in detail together with the geologic, hydrologic, and topographic conditions that may exist at individual sites.

Failure of Disposal Systems

If an individual sewage disposal system does not dispose of all the domestic wastes without creating a public health hazard or a nuisance,

it is not functioning properly and is said to have failed. Occasional malfunction due to inherent soil deficiencies is not acceptable. Some common manifestations of failure are the back-up of sewage or effluent into household fixtures, the development over absorption fields of areas that are wet or soggy with septic tank effluent, the overflow of effluent through lines that permit waste to flow to the surface in ditches or swales, the seepage of waste to the surface of the ground some distance from the absorption field, and the contamination of an existing or future water supply.

At least two basic types of failure can be recognized. One type occurs if the soil lacks sufficient permeability for the adequate transmission of sewage effluent. This restricted permeability may be due to an innate imperviousness of the soil, sealing of the soil by swelling under the influence of effluent, clogging of the soil with sewage solids and chemical precipitates, or a combination of these. Common manifestations of this failure type are the appearance of effluent in household fixtures or at the surface of the ground above absorption fields. The second type of failure occurs where there is sufficient, even excessive, transmission or seepage of sewage effluent through the soil, but the effluent appears at the surface of the ground some distance from the normal disposal area. In this case, the soil may be very permeable but is shallow from the surface to an impervious layer or the water table. The result may be a relatively rapid lateral movement of the effluent and its appearance at the surface in downslope areas such as ditches, curbs and gutters, or points of natural ground water seep. Where disposal system failures are considered in this report, the first type of failure will be referred to as due to a lack of "effluent transmission" and the second type of failure as due to "effluent seepage."

The contamination of ground water wells and the failure of seepage pit installations represent special geologic problems and will be discussed only incidentally.

PART II: SOIL CHARACTER IN RELATION TO RESIDENTIAL SEWAGE DISPOSAL

Soil evaluation with reference to individual sewage disposal systems requires consideration of the position, profile, and performance of the soil. By position is meant the position of the soil with respect to bedrock geology and geologic processes, to hydrologic features such as ground water and periodic flooding, and to topography or slope. The profile of a soil is its vertical section, seen from the surface to some depth, and represents a two-dimensional view of the component soil layers, referred to as horizons. Such features as the color, thickness, number, and arrangement of horizons with depth are called profile characteristics.

Soil performance includes the performance of such soil-dependent installations as septic tank absorption fields, roads, lightly-loaded structures, and even crops and natural vegetation. In some cases, a soil may be regarded as unsuited for individual sewage disposal systems on the basis of position, profile, or performance alone. Often, however, a careful consideration of the combination of these factors is necessary for proper soil evaluation.

Soil Position

Geology

Soils may be grouped geologically into two main categories, residual and transported. Residual soils lie directly upon the geologic materials from which they are derived, such as sandy soil over sandstone and silty soil over shale. Transported soils are derived from geologic materials that have been moved and deposited as soil, such as the alluvial soil of flood plains. For transported soils, the character of the uppermost few feet may bear little or no relation to the nature of the subsurface materials, and the prediction of the subsurface conditions on the basis of surface exploration is hazardous. In the case of residual soils, it is often possible to infer in some detail the nature of the bedrock from careful examination of the uppermost few feet of soil. Since substrata characteristics are important to sewage disposal, this practical difference between residual and transported soils is important.

Features of the rock below residual soils that are important are physical character, composition, and depth to first occurrence beneath the ground surface. Ideally, the rock should be porous and highly permeable and lie well below the ground surface. However, if the rock is sufficiently absorbent and permeable, its nearness to the surface may be important only in relation to the physical problem of installing a disposal system. Indeed, with certain rocky soils, the problem of installation limits their use. If the rock lies at a great depth below the surface, its permeability is of less importance. The composition of the rock controls, in part, the character of the derived soil. Certain rocks, usually those very high in bases, yield plastic soils of low permeability where the topography is smooth and the climate humid. Other rocks, such as micaceous schists, tend to result in friable, highly permeable soils. Any one rock formation results in a suite of soils depending on the hydrologic conditions and topography associated with the position of the material. This suite of soils is referred to as a catena.

For a sufficiently permeable soil, the depth to intact bedrock may determine whether or not an individual sewage disposal system fails. Where both the bedrock and topography are level and the bedrock

is within a few feet of the surface, sewage effluent tends to collect on top of the rock. If the rock has impaired permeability in the vertical direction, as with dense igneous intrusive rock and level-bedded limestones and shales, the effluent will build up to the surface of the soil. If the intact bedrock is associated with a shallow soil on a slope, the effluent will tend to flow along the surface of the rock downslope until it has cause to break to the surface at a point of slope change or bedrock outcrop. Highly fractured, closely jointed, fissured, or fissle rock may be highly permeable. Still, such permeable rock may be relatively nonabsorbent so that it allows sewage to travel some distance and appear as a contaminant in ground water. In all cases where the soil is thin, its suitability for sewage disposal must be viewed sceptically.

Common types of transported soils are those deposited by wind, glacial ice or glacial meltwater, water, and gravity. Wind deposited or aeolian soils are most commonly those of a type called loess. Loessal soils vary from thin to thick deposits of silty sand to clayey silt. Commonly, they are quite permeable, and the water table is well below the ground surface. In some cases where they occur in depressions or on smooth topography, they have weathered into tight, plastic soil having a high water table and slow permeability. Shallow loessal soils capping residual soil or rock are not uncommon and will have characteristics controlled in part by the nature of the substrata. The suitability of loessal soils for individual sewage disposal systems can be properly determined only after examination of the soil profile characteristics. The same may be said of glacial soils. Being highly variable in depth, grain size characteristics, permeability, and the nature of the substrata, glacial soils are difficult to characterize except on the basis of their in situ properties.

Water deposited soils range from vast marine deposits of the coastal plains to local alluvium along small streams. They may be composed of uniform sands with little or no fines, of silt and clay, or of materials of intermediate particle size. Although marine deposits tend to be uniform over relatively large areas, a characteristic of water deposited soils is horizontal and vertical variability, a result of the eccentricities of the transporting medium. Hence, it is difficult to predict soil permeability from a cursory knowledge of the geology.

Hydrologic position is of particular importance for transported soils. Some occur in areas that are presently subject to flooding and deposition, such as recent alluvium, and are therefore unsuitable for sewage disposal systems. Others lie low relative to the regional water table, such as in low-lying coastal areas, and thus provide generally

unsatisfactory conditions for sewage disposal. Those that occur in more upland positions generally have more definitive profile characteristics distinguished by definite layering due to weathering and soil-forming processes. Many of these are highly satisfactory for individual sewage disposal systems, but care must be taken to assess the permeability of the individual layers in the soil profile. In some cases, a combination of nearly level topography and soil-forming processes has resulted in the development of a compacted, relatively impermeable layer called a pan by pedologists, at a depth of from eighteen to forty inches. This seems especially common where the water-deposited material is less than a few feet thick over residuum. Hence, many landward fringes of terraces and coastal plain deposits must be held suspect.

Colluvium is soil material accumulated through the influence of gravity as local wash or erosion debris at the base of slopes, along local drainage ways, or in topographic depressions. Water often acts as a depositional aid. Like alluvium, colluvium may be relatively recent and still subject to periodic deposition. Also, it may be relatively old geologically so as to form topographic swells due to post-depositional incisement of streams. Recent colluvium often has the appearance of the soil from which it is derived. It is often friable and permeable and may be as thin as eighteen inches. Much of it appears well suited to workable sewage disposal installations, but invariably it must be rejected for that purpose because of its hydrologic position. It is subject to seasonally high ground water and seep; the natural collecting basin in which it lies may even be flooded for several days at a time in the spring. In contrast, old colluvium may also contain seepage water, but this seepage is usually at greater depth. Here, if the soil profile characteristics are favorable, sewage disposal systems may be satisfactory. However, considerable caution must be exercised in the evaluation of old colluvial soils. Some may be shallow over relatively impermeable residuum. Others may contain the compact, fairly impermeable horizon common among transported soils that are thin over residuum. Still others may be derived from rock materials which weather into relatively impermeable silt and plastic clay soils.

As with residual soils, transported soils are grouped into suites known as catenas. All soils of one catena are derived from similar soil-forming materials. For residual soils, the soil-forming material is the bedrock, and pedologic soil names change with changes in bedrock depth and drainage or degree of water-logging of the soil. Catenas of transported soils change with changes in the nature of the deposit, which are usually shown by grain-size differences, drainage, and geomorphic position. Typical changes in geomorphic position are river flood plain versus low or high terrace, low coastal plain terrace versus intermediate or high terrace, and recent, local colluvium versus older,

mountain footslope colluvium. Such differences in position are very important hydrologically.

Hydrology

The hydrologic position of a soil refers to its position with respect to surface and subsurface water. If a soil is more or less permanently waterlogged a short distance beneath its surface, this usually can be detected from the soil profile characteristics. More subtle are situations in which the soil is subjected to ground water seepage or flooding during only a few short periods of time each year. Such conditions must be recognized by estimating the ordinary behavior of surface and subsurface water. Low lying flood plain areas are subject to flooding however long it may have been since such floods were last reported. Natural depressional swales and drainage ways, often dry during some seasons, collect surface water in considerable quantities during periods of prolonged rain. If one properly examines an area of undulating topography, it is easy to visualize where surface water will collect and flow. The construction of homes and streets in such areas is seldom a deterrent to such flow. Individual sewage disposal systems subject to periodic flooding are undesirable.

Subsurface water attempts to flow with the surface topography, that is, parallel to the surface. It is often said that the water table is a subdued replica of the topography. Actually, the water is somewhat unsuccessful in this attempt because it cannot match the sharp slope changes and relatively large differences in elevation common to the surface topography. Consequently, the water table may be at considerable depth beneath the surface of a topographic high but break out onto the surface at the foot of a slope forming a seepage spot. Hence, relatively level land at the base of a slope often has a water table near the surface.

If the bedrock is of low permeability, or if the soil contains a slowly permeable layer, water that percolates into the soil will tend to collect at the top of this layer creating a perched water table. In low topographic positions, the fluid may have no readily accessible outlet and simply build up as a pond until it shows at the surface. On sloping topography, the water will tend to follow the slope until there is an abrupt slope change or the slowly permeable layer approaches the surface. At this point, seepage will appear at the surface. Any place where water tends to seep to the surface or collect is unsuitable for disposal systems.

Where the water table is controlled by such regional influences as rivers, large lakes, or an ocean, its position tends to be more permanent. Still, during prolonged dry spells, the soil may appear to

be relatively free of water to some depth. Uniform or mottled gray soil colors or a high organic matter content is indicative of a permanent high water table and imperfect drainage. Any soil that tends to be naturally water-logged for long periods of time will have some of these characteristics to some degree, regardless of the cause of waterlogging. These characteristics and their relation to soil water conditions are discussed under Soil Profile Characteristics.

Topography

Topography is an important clue to many geologic and hydrologic conditions. It is generally spoken of in terms of relief, approximately defined as given in Table 1.

The topographic analysis of a landscape together with a knowledge of the geology and hydrology of the area will allow an experienced earth scientist to predict with considerable accuracy the nature and position of the various soils therein. In strongly dissected terrain with hilly and rolling relief, the water table is usually at considerable depth. Still, shallow soils may be common especially on moderately

Table 1

Relief Nomenclature in Terms

of Dominant Slope Range*

Dominant Slope	Relief Nomenclature	
Per cent	Single Slope	Complex Slopes
0-2	level	level
3-7	gently sloping	undulating
7-15	sloping	rolling
15-25	moderately steep	hilly
25+	steep	steep

* From Soil Survey Manual (7)

steep slopes. Near the base of slopes, where they change from sloping to gently sloping, recent colluvium is common. Undulating and level land is often indicative of transported soils such as river floodplains and terraces, coastal and lake plains, glacial till plains, and areas of colluvial detritus. In such places, small differences in relief have

tremendous importance hydrologically with waterlogged soils often occurring in minor depressions. Broad, flat areas of residual soils may be mostly wet or highly plastic especially if underlain by dark, dense rock such as diabase or massive, fine-grained sedimentary rock. The slow surface drainage associated with level topography may result in a high water table and be a clue to slow subsurface drainage. Conversely, a well developed surface drainage system, such as that occurring in rolling topography, is often the mark of good subsurface drainage. An exception to this is karst topography associated with high-grade limestone bedrock. Here, surface outlets and streams of subsurface waters may not be apparent in the strongly undulating or rolling topography, but caverns and solution channels in the rock keep the regional water table low. Features of soils in such topography are highly variable depth to bedrock, pockets of clayey, seasonally wet soils in depressions, and fine-grained but highly permeable soils in the higher topographic positions. It is significant that soil characteristics and, hence, sewage disposal suitability may change markedly from one physiographic section to another. Similarly, within any one physiographic section, changes in slope generally coincide with changes in soil characteristics. But, within any one physiographic and geologic section, similar soils may be encountered on similar slopes.

Judgment of soil position for sewage disposal

The analysis of soil position for evaluation of the soil for sewage disposal suitability should be methodical and complete. In some cases, as for a low-lying flood plain, only a cursory examination of the terrain is necessary to rule out the possibility of a workable individual sewage disposal system. In most cases, however, systematic record taking and analysis will allow more accurate decisions to be made and, if not decisive in themselves, the records and analysis will form an important supplement to other data.

An analysis of two soils in Loudoun County, Virginia, with reference to position alone is given below (6):

Soil Name.* Pedologic: Croton silt loam, level phase.

Unified: ML

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* For clarification of the pedologic name, see section on reports and maps in Part IV of this report. "Unified" refers to the classification of the soil by the Unified Soil Classification System as outlined in Engineering Soil Classification for Residential Developments (3).

Geology. Residual from shale, shaley sandstone, and sandstone; may contain some local alluvium; bedrock occurs $1\frac{1}{2}$ to 8 feet below the surface and has variable permeability.

Hydrology. Water table occurs about 1 foot below the surface; subject to seepage in many places.

Topography. On level slope in generally undulating topography; occurs on upland flats at the heads and upper courses of drainageways.

Suitability for individual sewage disposal system. Rated as unfavorable on the basis of the occurrence of alluvial materials, shallow bedrock depth, high water table, water seepage, and generally unfavorable topographic position for good subsurface drainage.

Soil Name. Pedologic: Glenelg silt loam, undulating phase.

Unified: ML

Geology. Residual from mica schist; bedrock invariably very far below the ground surface except for occasional small outcrops of vein quartz.

Hydrology. Seasonally high water table is many feet below the ground surface; regional water table slightly above bedrock.

Topography. Occurs on moderately low upland ridgetops with gentle slopes in rolling terrain.

Suitability for individual sewage disposal systems. Position rated as very favorable on the basis of depth to bedrock and water table, gentle slope, and upland position.

Soil Profile Characteristics

The soil profile is the soil in cross-section from the surface to some depth. The agronomist, interested mostly in crop growth, often limits his examination and description of the soil profile to the uppermost six to ten feet. The foundations engineer may find it necessary to characterize a deep, transported soil to depths of as much as 200 feet. The sanitary engineer concerned with individual sewage disposal systems may find the uppermost few feet of soil the most significant with reference to septic tank absorption field and absorption bed installations, but he must also concern himself with deep subsoil and rock strata conditions when considering seepage pits and ground water contamination.

The soil profile is referred to here mostly in terms of the uppermost few feet of soil and with special reference to absorption field disposal systems.

Soil profile characteristics are a function of the geologic materials from which the soil is derived; the associated topography and hydrology, including climate; the nature of the forces of disintegration and decomposition that cause the geologic materials to decay; the nature of the pedologic soil-forming process resulting in the genesis and accumulation of organic matter, clay, or products of mineral decay; and the amount of time during which the soil has remained in its environment. These varied, complex, and interdependent factors provide a nearly infinite variety of soils. Fortunately, the derived soils tend to fall into certain natural groupings having profile characteristics in common. An orderly method of examining, describing, and classifying the soil profiles has been devised (see Table 2). The system has been used to considerable advantage for the correlation of soils with crop performance and there is ample evidence that similar success can be achieved in the study and prediction of soil suitability for individual sewage disposal systems and other engineering uses.

Soil horizons

Deep within transported soils one often finds distinct soil layers reflecting geological transportation and deposition. Such layers, which may not have changed appreciably since deposition, are generally called strata. Different from these are the layers which occur in the uppermost few feet of soil and were formed from processes other than geologic. Such layers reflect the addition of organic materials from plant growth, the downward movement and, in places, subsequent deposition or precipitation of material suspended or dissolved in water, the bleaching action of a high water table or percolating waters containing organic acids, the coloring processes of iron segregation and oxidation, or the development of cracks, fissures, or compacted layers through alternate wetting and drying. These layers depend for their characteristics not only on the nature of the geologic materials but on climate, vegetation, and time as well. They are called horizons.

The various symbols of horizon nomenclature are discussed in several readily available reports (3, 5, and 7) and illustrated in Table 2. Of primary interest to engineers are the B and C horizons. The B horizon is often described as being absent in recently deposited soils such as in alluvium and colluvium and in shallow soils on steep topography. Hence, the absence of a B horizon may be an important clue to conditions unfavorable for sewage disposal. Extraordinary B horizons, such as a hard, compacted "pan" layer or a

massive, gray, plastic, "gley" layer, must also be viewed with considerable suspicion. Since B horizons tend to be zones of clay accumulation or cementation, they are generally less permeable than the underlying and surface materials. A very critical examination of their characteristics, which may not be evident from the nature of the surface soil, is necessary for a proper evaluation of the soil for sewage disposal or other engineering uses.

The nature of the C horizon is largely controlled by the geology of the soil-forming materials. In residual soils, a thorough examination of the C horizon will often allow one to recognize the character of the bedrock, its depth, and approximate permeability. In transported soils, one may encounter thin strata of slowly permeable silt and clay in soils otherwise open and rapidly permeable. For seepage pit installations, a thorough examination of the C horizon is mandatory. There are cases where the seepage pit is the logical solution to installing a workable sewage disposal system in a soil with a slowly permeable B horizon, an absorbent, rapidly permeable C horizon, and a sufficient depth to the bedrock and the water table.

Soil texture

Soil texture refers to the relative proportions of the various size groups of individual grains of soil. It is concerned with grain size and gradation.

The term "texture" occurs in all pedological* soil survey reports**. The division of grain sizes into fractions with arbitrarily standardized boundaries is often called a textural classification. It is not actually a soil classification but rather a grain-size scale, and it is used in this sense in soil survey reports. The size groups are commonly called sand, silt, and clay. Pedological reports use various combinations of these terms usually in conjunction with the word "loam," which is an agricultural term not generally understood by engineers. If the essential grain-size scale and gradation meanings of the pedological uses of these terms are kept firmly in mind, the pedological textural descriptions can be deciphered with a little effort. Since the pedological soil survey reports are an important source of information for judging soils for sewage absorption fields, this effort can be quite fruitful.

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* Pedological is a broad term which includes both the agricultural and the engineering aspects of national soil surveys.

** Soil survey information is obtainable either from the Soil Conservation Service of the Department of Agriculture or from state colleges and state Agricultural Experiment Stations.

A Theoretical Soil Profile Showing Horizon Nomenclature*

	PLANT DEBRIS ON THE SOIL USUALLY ABSENT ON SOILS DEVELOPED UNDER GRASSES	A_{00}	LOOSE UNDECOMPOSED PLANT DEBRIS
		A_0	MATTED PLANT DEBRIS PARTIALLY DECOMPOSED
THE SOLUM (SOIL BY PEDOLOGICAL DEFINITION)	**A** HORIZONS OF DOMINANTLY INORGANIC MATERIALS CHARACTERIZED BY MAXIMUM HUMUS ACCUMULATION MAXIMUM ELUVIATION (REMOVAL OF CLAY) DEVELOPMENT OF GRANULAR, CRUMB, OR PLATY STRUCTURES	A_1	DARK COLORED HORIZON OF MAXIMUM ORGANIC MATTER CONTENT BEST DEVELOPMENT OF CRUMB OR GRANULAR STRUCTURE MAY OR MAY NOT BE ELUVIATED MAY BE ABSENT FROM SOME SOILS ALTERED BY CULTIVATION, ETC. COMMONLY THICK IN CHERNOZEMS AND PRAIRIE SOILS, VERY THIN OR ABSENT FROM PODZOLS
		A_2	LIGHT COLORED HORIZON WITHIN THE A GROUP HAVING MAXIMUM ELUVIATION (MINIMUM CLAY),MINIMUM ACCUMULATION OF ORGANIC MATTER,AND MINIMUM DEVELOPMENT OF GRANULAR STRUCTURE COMMONLY HAS WEAKLY DEVELOPED STRUCTUAL UNITS, PLATY AND CRUMB ARE MOST COMMON PROMINENT IN POZDOLS, PLANOSOLS,AND SOLODIZED-SOLONETZ SOILS
		A_3	TRANSITION HORIZON, MORE LIKE THE A THAN THE B, SOMETIMES ABSENT COMMONLY HAS COURSE GRANULAR TO POORLY DEVELOPED PRISMATIC OR BLOCK STRUCTURE
	B HORIZONS OF ILLUVIATION CHARACTERIZED BY ACCUMULATION OF SILICATE CLAY AND OXIDES OF IRON OR ALUMINUM; OR BLOCKY, PRISMATIC OR COLUMNAR STRUCTURES; OR DEVELOPMENT OF STRONGER RED OR YELLOW COLORS; OR SOME COMBINATION OF THESE FEATURES	B_1	TRANSITION HORIZON, MORE LIKE THE B THAN THE A, SOMETIMES ABSENT COMMONLY HAS WEAKLY DEVELOPED NUTTY TO PRISMATIC OR BLOCKY STRUCTURE
		B_2	HORIZON OF MAXIMUM ACCUMULATION OF SILICATE CLAY OR OXIDES OF IRON AND ALUMINUM OR MAXIMUM DEVELOPMENT OF BLOCKY OR PRISMATIC OR COLUMNAR STRUCTURE OR DEVELOPMENT OF STRONGER RED OR YELLOW COLORS OR SOME COMBINATION OF THESE FACTORS
		B_3	TRANSITION HORIZON, MORE LIKE B THAN C
	C RELATIVELY UNALTERED UNCONSOLIDATED PARENT MATERIAL	C_1	SLIGHTLY ALTERED PARENT MATERIAL
		C_2	PARENT MATERIAL OF VARIABLE DEPTH
	D ANY STRATUM UNDERLYING THE C OR THE B UNLIKE THE MATERIAL FROM WHICH THE SOIL HAS FORMED	D	D_r IS USED FOR CONSOLIDATED ROCK LIKE THAT FROM WHICH THE C HAS DEVELOPED

* James H. McLerran, State of Washington Engineering Soils Manual (Washington: Washington State Council for Highway Research, 1954), pp. 4-5.

The use of the terms "silt" and "clay" for arbitrary grain-size fractions is misleading. Such terms should be reserved exclusively for soils having corresponding physical characteristics as is done in the Unified Soil Classification System, which has been adopted for use by the Federal Housing Administration. The USCS recognizes two major textural divisions of soils, coarse-grained and fine-grained. When "texture" is used in this report, it refers to the USCS divisions. Detailed field identification procedures and a discussion of the general characteristics of these soil components are given in FHA Bulletin No. 373 (3). Approximate qualitative characterizations of these soil fractions are given below:

Coarse-grained Soils:

Sand - Particles less than about 1/16 inch in diameter but large enough to be seen with the naked eye or felt. Squeezed in the hand when dry, sand will fall apart when the pressure is released. Squeezed when moist, it will form a cast but will crumble when touched. Settles rapidly in water.

Fine-grained Soils:

Silt - Particles like sand in composition but so fine as to feel soft and floury. When wet, readily runs together and puddles. When moist, it will form a cast that will bear careful handling, but when squeezed between thumb and finger, it will not "ribbon" but will give a broken appearance. Drys with little shrinkage into lumps that can be readily crushed to a palpable powder between the fingers. Powder easily rubs off surface of dry samples or hands. Settles from suspension in 1 to 60 minutes.

Clay - Particles so small they settle very slowly in water. When moist, it may be sticky, plastic, cohesive, ropy, and slick so as to form a long, flexible "ribbon" when squeezed between the thumb and finger. When kneaded, it does not crumble readily but tends to work into a heavy, compact mass. It will form a cast that will bear much free handling without breaking. Drys slowly with shrinkage into hard lumps or clods that will not powder.

Silt and clay are referred to as fines or fine-grained soil. Sand is called granular or coarse-grained. Sand may have its permeability drastically lowered by the presence of fines. These fines can be detected in sand by their propensity to cloud water into which such sand may be placed or, in the case of dry sand, cloud the air when the sand is thrown.

According to the Unified Soil Classification System, coarse-grained soils, including gravel, are designated as GW, GP, SW, and SP, as given in Engineering Soil Classification for Residential Development (3). Such textures are favorable for individual sewage disposal systems. Coarse-grained soils with fines are designated GM, GC, SM, and SC. Such soils, together with silty and clayey soils with low to medium plasticity, are less desirable for sewage disposal, and must be evaluated cautiously. Soils with high plasticity (MH, CH, and OH) must be viewed very skeptically or rejected outright for sewage disposal systems unless all other significant characteristics of the soil are very favorable.

Agronomic descriptions of texture, which include the perplexing term "loam," are exact and refined in their definitions. Those definitions involve particle size alone. To interpret agronomic textural descriptions in terms of the Unified Classification System and engineering properties of soil, one must consider the consistency of the soil also.

Soil consistency

Consistency is applied to the degree of cohesion between the soil particles and the resistance to deformation or rupture of soil aggregates. Consistency changes with both soil character and moisture content. Engineers have found that for any one soil the relations between change in water content and consistency are especially significant. Accordingly, they have adopted tests for the definition of the water content range through which a soil behaves as a plastic material, defined as the plasticity index or PI of the soil. Although it applies to soil in the moist, disturbed state, this plasticity concept is of great value in characterizing soil and predicting its engineering properties (3).

In the field, the plasticity of fine-grained soils (coarse-grained soils are essentially nonplastic) may be predicted from dry strength and the "plastic ribbon test." Dry strength refers to the resistance of a dried lump of soil to crushing with the fingers. Nonplastic soils have no or very little dry strength. Low dry strength, allowing easy crushing in the fingers, is typical of soils with low plasticity. High to very high dry strength, making crushing in the fingers very difficult or impossible, typifies soils of high plasticity. The plastic ribbon test consists of alternately rolling and kneading a lump of remoulded, moist soil. As the lump is rolled into a thread, the pressure required should be noted. Tough threads are characteristic of highly plastic clays, whereas a weaker thread is usual for soils of low plasticity. Slightly plastic soils give very weak threads, and a spongy feel indicates organic soil. The threads of highly plastic clays will hold together as the soil is gradually dried with working, and when buffed with a fingernail, they will take a high polish. The toughness of the thread

decreases with a decrease in plasticity (2).

Any soil with high plasticity has poor or at best questionable potential for satisfactory individual sewage disposal systems. When wet, such soil is almost impermeable. When dry, the soil may contain large cracks and fissures which allow an initially high rate of percolation of water, but as the soil becomes wet, it may swell so as to seal cracks and pores. Nonplastic soils are not necessarily highly permeable since sands containing large amounts of silt may have neither plasticity nor appreciable permeability. Still, low plasticity together with favorable soil "structure" suggest favorable conditions for sewage disposal.

Soil structure

From the standpoint of the pedologist, soil "structure" refers to the aggregation of primary soil particles into compound particles, or clusters of primary particles, which are separated from adjoining aggregates by planes of weakness (7). Each natural soil aggregate is called a "ped." For soil mechanics, soil structure is defined as "the arrangement and state of aggregation of soil particles in a soil mass (3)." The soil mechanics definition is readily applicable to mechanical problems relating to saturated and nearly saturated soils, before and after disturbance, and refers more to microscopic and submicroscopic particle arrangements than does the pedologic concept. The pedologic definition deals with the visible aggregates common in soils. Because it bears heavily on soil permeability, the pedologic concept is particularly important to soil evaluation for sewage disposal systems. The important types of pedologic structure are defined in reference (3).

Soils with discernable pedologic structure commonly have good permeability characteristics except where this structure is of the platy type. Where soil breaks into flat, horizontally oriented, platelike aggregates, it is often indicative of a hard, compact layer with slow permeability. Soils without pedologic structure may be rapidly permeable if coarse-grained and noncohesive but very slowly permeable if fine-grained and cohesive. The latter condition is described as massive and is commonly associated with a high water table or permanent saturation.

Structural stability, or grade of structure, is more important than structural type or class. According to the United States Department of Agriculture (7), the various grades of structure are as follows:

Structureless - That condition in which there is no observable aggregation or no definite orderly arrangement of natural lines of weakness.

Weak - - - That degree of aggregation characterized by poorly formed indistinct peds that are barely observable in place. When disturbed, soil material that has this grade of structure breaks into a mixture of few entire peds, many broken peds, and much unaggregated material.

Moderate - That grade of structure characterized by well formed distinct peds that are moderately durable and evident but not distinct in undisturbed soil. Soil material of this grade, when disturbed, breaks down into a mixture of many distinct entire peds, some broken peds, and little unaggregated material.

Strong - - That grade of structure characterized by durable peds that are quite evident in undisplaced soil, that adhere weakly to one another, and that withstand displacement and become separated when the soil is disturbed. When removed from the profile, soil material of this grade of structure consists very largely of entire peds and includes few broken peds and little or no unaggregated material.

In some cases strong structure reflects the high binding action of organic material intimately incorporated in soil, such as near the surface of grassland soils. But usually, strong structure indicates a highly cohesive, plastic type of soil. Hence, although strongly structured soils may yield an initially high rate of percolation, their ability to absorb and transmit sewage effluent over the long term must be questioned. Similarly, soils with moderate structure tend to be more plastic in the disturbed state than those with weak structure and may be less suited to sewage disposal. The cracks and fissures that attend structure in an undisturbed soil and result in relatively high permeability may be clogged and sealed during the installation of a disposal field. Later, during the operation of the system, the solids and chemical precipitates may also contribute to this stoppage. Some soil may swell enough to close these channels when it becomes soaked in effluent. The extent of permeability reduction by these means is currently being studied, but it is still not clear if the large majority of strongly structured soils must be assessed as unfavorable on this basis. Investigations by field scientists of structure versus disposal system performance in each physiographic region would yield valuable correlations.

Structure develops in soils as the result of slow soil-forming processes. Accordingly, weak structure is a feature of such very young soils as those derived from recent alluvium and colluvium. Often, it is necessary to rely on such profile characteristics to recognize these unfavorable soils.

One should bear in mind that pedologic structure is a characteristic of undisturbed soil and that it is readily destroyed by remoulding the soil. Accordingly, a fresh profile exposure such as a pit, trench, or road cut is necessary for its study. Structure has been largely altered or destroyed in soil at the surface of old exposures and in samples removed by most borings.

Soil drainage condition

When dealing with foundations and earth structures, the engineer thinks of soil drainage in the active or dynamic sense as referring to the rapidity and extent of the removal of water from soil in relation to additions, and flow through the soil in relation to energy losses. For the study of soil profiles in relation to sewage disposal or other engineering aspects, a concept of the soil drainage condition is especially valuable. As a condition, soil drainage "refers to the frequency and duration of periods when the soil is free of saturation or partial saturation" (7) as determined by inference by the field scientist.

Several drainage condition classes have been defined in relation to hydrologic conditions as follows (7):

Very poorly drained - Water is removed from the soil so slowly that the water table remains at or near the surface the greater part of the time. Soils of this drainage class usually occupy level or depressed sites and are frequently ponded.

Poorly drained - Water is removed so slowly that the soil remains wet for a large part of the time. The water table is commonly at or near the surface during a considerable part of the year. Poorly drained conditions are due to a high water table, to a slowly permeable layer within the profile, to seepage, or to some combination of these conditions.

Imperfectly or somewhat poorly drained - Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time. Imperfectly drained soils commonly have a slowly permeable layer within the profile, a high water table, additions through seepage, or a combination of these conditions.

Moderately well drained - Water is removed from the soil somewhat slowly so that the profile is wet for a small but significant part of the time. Moderately well drained soils commonly have a slowly permeable layer

within or immediately beneath the solum, a relatively high water table, additions of water through seepage, or some combination of these conditions.

Well-drained - Water is removed from the soil readily but not rapidly. Well-drained soils are commonly intermediate in texture although soils of other textural classes may also be well-drained. A well-drained soil is commonly said to have "good" drainage.

Excessively drained - Water is removed from the soil very rapidly. Most of the soils have little horizon differentiation, are sandy and very porous, and may occur on steep slopes.

Very poorly drained, poorly drained, and imperfectly drained soils are unsuited for individual sewage disposal systems. Moderately well-drained soils are highly questionable but may be suited if very highly permeable and associated with well-drained soils rather than soils of poorer drainage. Well-drained soils may be suitable for sewage disposal if sufficiently permeable and favorably located. Excessively drained soils should be considered favorable only if they are sufficiently deep above bedrock and on topography that precludes an effluent seepage failure.

Strictly speaking, drainage class is not so much a profile characteristic as it is a profile condition inferred on the basis of profile characteristics. The most important guides to drainage class are soil color and organic matter.

Soil color and organic matter

With few exceptions, the color of soil comes from organic matter and iron. Organic matter usually imparts a dark brown, grayish brown, or black color to soil material. In the humid, timbered regions of the United States, well-drained soil contains little organic matter below six to eight inches unless it is recently transported topsoil. In the less humid, colder, grassland regions of the Prairies and Great Plains, organic matter may persist to some depth in the soil. Within any one climatological region, variations in organic matter content and, hence, in soil color occur with variations in drainage class. The more poorly drained a soil, the more organic matter it is likely to contain.

The light brown, yellow, or red colors in soil are a result of various compounds of oxidized and hydrated iron. These may be considered the rust of soil. Such rusting and maintenance of iron in the oxidized state depends on air. If the soil remains saturated with water, the rust literally dissolves in a series of complex reactions, and the yellow or red color becomes dull and discontinuous or it disappears leaving gray. Very recently formed soils or those that have

never been in an air environment for any prolonged length of time may never have been bright in color. The brightest colors in soils usually occur near the surface but not so near that they are masked by organic matter or have been washed severely by water containing organic acids. A color may be discontinuous, or it may form a matrix containing splotches or short ribbons of another color. Such splotches are called mottles. Gray mottles in a red or yellow matrix may be due to a periodic saturation of the soil with ground water or impaired permeability. Thus, the existence of these mottles and their depth beneath the surface are a sensitive indication of drainage class. With poorer drainage, the gray mottles tend to fuse and form a gray matrix. Finally, a soil horizon may be formed in which the material is bluish gray or olive gray, more or less sticky, compact, and structureless. Such soil is referred to as gley and the process of its formation as gleying or gleization.

Soil drainage class is generally related to organic content and color as outlined below (7):

Very poorly drained - In the timbered regions, commonly have dark-gray or black surface layers and are light gray with or without mottlings in the deeper part of the profile. In the grassland regions, commonly have mucky surfaces with distinct evidences of gleying.

Poorly drained - In the timbered regions, may be light gray from the surface downward with or without mottlings. In the grassland regions, may have slightly thickened dark-colored surface layers.

Imperfect or somewhat poorly drained - In the timbered regions, generally are uniformly grayish, brownish, or yellowish near the surface and commonly have mottlings below 6 to 16 inches depth. Among the dark-colored soils of the grasslands, have thick, dark, surface soils high in organic matter and faint evidences of gleying below.

Moderately well drained - In the timbered regions, have mostly uniform colors in the uppermost two feet of soil but mottlings at less than 36 inches depth. Among the dark-colored soils of the grasslands, profiles have thick, dark surface soil with yellowish or grayish faintly mottled soil below.

Well-drained - In the timbered regions, generally free of grayish mottlings to depths of several feet. In the grasslands,

the dark-colored soils have thick, dark surface soil underlaid by reddish, brownish, or yellowish soil.

Excessively well drained - Below the surface, free of drainage mottlings but having any of a variety of colors imparted by soil-forming material.

The occurrence of mottling at less than two feet depth in a soil is sufficient cause to regard it as unsuitable for individual sewage disposal systems <u>if this mottling is due to impeded drainage</u>. Although most bluish gray or olive gray color in soils can be traced to retarded drainage, there are many situations where the color of the geologic soil-forming materials has an overriding influence on the coloring action of pedologic processes. An example is the bluish gray triassic shale near igneous intrusives which forms a soil that is bluish gray throughout. One must compare a soil suspected of being poorly drained to soils having better drainage and derived from similar materials in order to evaluate the extent to which color is reflecting drainage class. Also, color must simply be used as a guide, not a single deciding criterion.

Other important profile features

Other important profile features include stoniness or rockiness, state of compaction or cementation of individual soil layers, and the location of plant root concentrations. Stoniness, the occurrence of many loose cobbles and boulders in the profile, is usually expressed in terms of the percent of the soil mass that appears to be taken up by these large particles. It is important both to the mechanics of installing individual sewage disposal systems and to the absorption potential of the soil. Soils which consist mostly of stones may transmit sewage effluent rapidly without absorbing it in the sense of allowing biological rendering. Hence, the effluent is likely to find its way to potable groundwater or to the surface of the ground downslope. Very rocky soils, characterized by many bedrock outcrops or the protrusion of large boulders, have obvious limitations for the mechanics of installation.

Cemented or compacted soil layers, referred to by pedologists as <u>hardpans</u> or <u>fragipans</u>, may be identified by the resistance they offer to hand excavation or augering. They are often associated with the occurrence of coarser particles in the profile, even gravel, and the tendency for the soil to break into large, platy peds. Some such layers are hard only when dry; however, they are not often wet because of their low permeability. Where they occur, they preclude the use of an individual sewage disposal system unless they are thin and the soil below them is especially permeable. In this case, deep absorption

field or seepage pit installations might be workable.

Another clue to the recognition of slowly permeable layers is the behavior of plant roots. Tree roots require air and will grow vertically only so long as they are able to penetrate the soil and stay above the zone of permanent saturation. Hence, shallow, horizontal spreading of roots indicates adverse conditions for sewage disposal.

Judgment of profile characteristics for sewage disposal

Ideally, the soil profile should be examined at a fresh exposure to a depth of about six feet or bedrock. Where this is impractical, valuable information can be secured from a small auger boring three feet deep. However, such borings should be supplemented with the study of the position and performance of the soil, supplementary nearby borings, and the examination of any road cuts, pits, or trenches available in the general area. Like the analysis of soil position, soil profile study and description should be as methodical and complete as practical. Two profile descriptions from Loudoun County, Virginia, are given below as examples (6):

Soil Name: Pedologic: Croton silt loam.

Unified: ML

Surface Soil: 0 to 9 inches, friable silty soil (ML) faintly mottled with brown and gray; weak platy structure.

Subsoil: 9 to 16 inches, firm silty clay, slightly plastic when wet (ML-CL); distinctly mottled brown and gray; strong subangular blocky structure.
16 to 34 inches, slightly plastic silty clay (ML-CL), hard when dry; distinctly mottled red and gray; moderate subangular blocky structure.
34 to 42 inches, friable silty soil (ML) distinctly mottled with red and gray; contains much partly weathered shaley sandstone.

Bedrock: 42 inches, red, horizontally bedded, hard shaley sandstone.

Suitability for Individual Sewage Disposal System: Rated as unfavorable on the basis of distinct mottling in the subsoil and unfavorable bedrock conditions.

Soil Name: Pedologic: Glenelg silt loam.

Unified: ML

Surface Soil: 0 to 7 inches, brown to yellowish brown, very friable silty soil (ML); moderate granular structure.

Subsoil: 7 to 24 inches, strong-brown, friable clayey silt (ML); moderate subangular blocky structure; small mica flakes and quartz gravel particles are common.
24 to 36 inches, light reddish-brown, very friable, soft, highly micaceous material of decomposed schist; a few pieces of quartz gravel and fragments of hard schist can be found.

Suitability for Individual Sewage Disposal System: Rated as favorable on the basis of soft, friable, apparently permeable and well-drained soil.

Soil Performance

One of the most valuable aids to predicting the behavior of a soil is a study of its past and present performance as a part of a sewage disposal system. This may be done with systematically kept records correlating soil character and performance within each geologic region including follow-up studies on soils rated favorable for individual sewage disposal systems. Of more immediate use, however, are field observations. Where possible, the nature of the vegetation and vegetation changes should be noted, physical behavior of the soil when cultivated or during the installation of structures should be observed, and the performance of roads and individual sewage disposal systems should be studied.

Vegetation

The character of natural vegetation tends to change with changes in soils. Of course, the type of vegetation depends as well upon the climate and history of the area. In each area, the investigator should notice the plant types as he studies the soils. Soon, he may detect certain "indicator" species that belie poorly drained conditions, soils thin above bedrock, or deep, well-drained soils. Also, certain features of vegetation may strike his eye, such as stunted growth and yellowed foliage, which indicate unfavorable conditions. Trees on shallow soils or soils with a compacted horizon find poor anchorage so that "wind throws," trees that have been uprooted by wind, are common. The lateral spreading of roots may be inferred by noting excessive thickening at the base of tree trunks. In pastured lands, grass and weed species tend to change with hydrologic conditions. Local alluvial and colluvial positions tend to support good growth in dry seasons, while grass on thin soils near ridge crests suffers from lack of water.

Certain cultivated crops are very sensitive to soil conditions. Many of the productive soils are those best suited to individual sewage disposal systems. Where alfalfa grows well year after year, the soil is almost invariably suited to sewage disposal. In fields where the growth of alfalfa is discontinuous, one should seriously question the positions where the crop has failed. Corn, being an annual crop, grows well in flood plain and colluvial soils. However, excessively drained and the more poorly drained soils result in stunted, yellowed corn. As a general rule, the more favorable soils are those being actively cultivated on prosperous, well-kept farms.

Mechanical behavior

Soils favorable for sewage disposal are generally favorable for other engineering purposes. They are commonly easy to excavate, have good compaction and stability characteristics, and provide a good subgrade for roads. Accordingly, soils which have created problems in the design and construction of structures and the installation of pipelines should be viewed suspiciously for sewage disposal. Poorly performing roads that undergo spring breakup tend to indicate a high water table, an unstable subgrade, swelling soils, or, in regions with cold winters, silty soils.

Performance of individual sewage disposal systems

The performance of existing individual sewage disposal systems is one of the best criteria on which to base an evaluation of a soil. However, care must be exercised in its use. Although the large majority of failures of recently installed systems are due to unfavorable soil conditions, faulty design may also be responsible. In the case of an effluent transmission failure, one should try to determine if the entire absorption field has been put to use or if for some reason the sewage effluent has broken to the surface without having access to the entire field. In the latter case, soil may not be solely responsible for the failure. Caution must also be taken in assuming that a disposal system is a complete success. It may take several years for a faulty system to show distinct signs of failure, and then failure may be only seasonal. Hence, working systems are no absolute criterion on which to base a favorable rating. Most important of all, one must properly correlate the soil associated with the observed installations with the soil in question. This may be done after carefully weighing position and profile characteristics and such soil and geologic maps as may be available. Ideally, one should have a firm soils correlation and should carefully study several systems varying in age from a few to several years old. Still, even one malfunctioning system is cause for considerable suspicion.

PART III: RATING SOILS FOR RESIDENTIAL SEWAGE DISPOSAL

The Rating Scheme

As implied in the foregoing section, rules of thumb are difficult to establish for rating soils for individual sewage disposal systems.* The suitability of the soil depends on a large number of factors, some of which may be unique to a geologic region, and these factors must be weighed in relation to one another. For instance, one may tolerate a higher water table, lower drainage class, or shallower depth to bedrock for coarse-grained, highly permeable soils on level topography than for fine-grained, less permeable soils on undulating topography. Still, a large body of information such as that gathered from field studies is of value only in so far as it can be systematically processed and summarized. This suggests some linear numerical notation which will allow weight factors to be dealt with arithmetically. But most schemes of this type trip upon the general nonlinearity of natural phenomena and fall short of taking care of the exceptions.

One may describe the suitability of a single soil condition or the soil as a whole in terms of three ratings: favorable, conditional, and unfavorable. Favorable should be applied only when there are no unfavorable circumstances. Conditional may be applied only when no unfavorable circumstances are known, but knowledge is incomplete or some circumstances are questionable. Unfavorable must be applied if any unfavorable circumstances are known with certainty. If three general items, such as position, profile, and performance, are being used to arrive at a general soil rating, or if three specific terms, such as geology, hydrology, and topography, are being used to arrive at a rating for one general item, such as position, the following rules are useful:

1. The rating is favorable when two or more of the three items are favorable and none is unfavorable.

2. The rating is conditional when two or more of the three items are conditional and none is unfavorable.

3. The rating is unfavorable when any of the items is unfavorable.

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* The percolation test has been used as a single criterion for determining soil suitability for sewage disposal (4), but the long-term ability of a soil to absorb sewage is <u>not</u> necessarily a function of its short-term ability to transmit water (8). Such factors as swelling, clogging, topography, and seasonal hydrologic conditions are not properly evaluated with the test. Its best use may lie in the fact that soils that fail to pass the test are definitely unsuited for leaching fields.

The three suggested items on which a soil rating might be based are position, profile, and performance. Three components of each of these and circumstances under which they might be rated as unfavorable or conditional are given in Table 3. The Table is not meant to apply to soil fill materials.

Soil rated as unfavorable for individual sewage disposal systems is not necessarily unfavorable for residential development. It might be feasible to develop the land with municipal sewerage, "package" disposal plants, or oxidation ponds. Also, it is not to be assumed that every individual sewage disposal system installed in favorable soil will be trouble free. Inadequate design, poor installation techniques, abuse during use, or improper maintenance may cause a system to fail as certainly as unfavorable soil. A far greater problem is that of conditional soils. They are difficult to diagnose and so widespread as to make their wise utilization of great economic importance.

The Problem of Conditional Soils

As indicated above, soils must be rated as conditional where soil conditions are of undetermined suitability for individual sewage disposal systems. This may be because of soil character, a lack of definite field data, or a combination of these. The soil may be of a very heterogeneous nature with some small areas favorable and some unfavorable for sewage disposal. In other cases, the soil profile may be unfavorable in part, perhaps in the uppermost few feet. In still other cases, the soil may be relatively homogeneous in both profile and areal extent but have marginal characteristics so that workable disposal systems may be obtained only by applying certain modifications of system design or installation techniques. All of these situations and their possible solutions must be recognized, analyzed, and given special attention.

Geographically heterogeneous soils

Two or more soils of differing suitability for individual absorption field systems may be intimately associated geographically so that it is difficult to apply a generally applicable rating to the area in which they occur. In this case, the area is conditional in general, but it may still be usable. If moderately large plots are delimited for each residence, it is possible that many such plots will contain areas of favorable soil large enough for the proper placement of an absorption field system. Unfortunately, if all systems in a development are not carefully placed, one or more may fail and cause an undesirable environment for adjacent residences.

It is not uncommon to find areas of geographically heterogeneous soils in which variations of soil position or profile over very short distances yield a complex pattern when viewed areally. Heterogeneous

Table 3
Soil Features Significant to Individual Sewage Disposal Systems
with Examples of Conditional and Unfavorable Situations

Feature	Item	Condition	Conditional Situations	Unfavorable Situations
Position	Geology	Residual soil	Bedrock rapidly permeable and less than 3 feet from the surface or slowly permeable and less than 6 feet from the surface.	Bedrock rapidly permeable and less than 2 feet from the surface or slowly permeable and less than 4 feet from the surface.
		Transported Soil	No deposition in recent past but less than 6 feet thick over a layer with low permeability.	Deposition still occurring or less than 4 feet thick over a layer with low permeability.
	Hydrology	Surface Water	With no sign of recent flooding, in short drain,* on high part of large flood-plain, or on low terrace.	In long drain,* on small flood-plain, low part of large flood-plain, or with signs of recent flooding.
		Groundwater and Seepage	At times, water table** less than 4 feet from the surface or water seeps out less than 100 yards downslope.	At times, water table** less than 2 feet from the surface or water always seeps out less than 100 yards downslope.
	Topography	Slope	Greater than 15%.	Greater than 25%.
		Position	At crest of slope greater than 15%, foot of slope greater than 7%, or in depression.	Not applicable.

* "Drain" refers to a natural elongated surface depression that intermittently transmits water. A short drain is less than 100 yards long, a long drain more than 100 yards.

** Water table is defined as the level of zero peizeometric pressure, usually indicated in permeable soils by the free water surface in an open hole.

Table 3 (continued)

Feature	Item	Condition	Conditional Situations	Unfavorable Situations
Profile Characteristics	Texture and Consistency	Coarse-Grained Soil	Contains fines, GM, GC, SM, and SC, or poorly graded and dense; hard or compact when dry.	Contains highly plastic fines or drys in place to very hard, compact, or cemented soil.
		Fine-Grained Soil	Slightly plastic or sticky when wet, firm, not friable when moist, and slightly hard when dry; ML, CL, or OL.	Plastic and sticky when wet, firm or tough when moist, and hard to very hard when dry; MH, OH, CH.
	Structure	Type	Structureless and slightly cohesive or somewhat platy.	Massive and highly cohesive or distinctly platy.
		Stability	Strong, large, durable peds.	Not applicable.
	Drainage Condition	Color and Organic Matter	Bluish-gray or olive-gray mottlings at less than 3 feet from the surface; or thick, dark surface, then mottling.	Dull or grayish near surface, gray mottlings less than 2 feet from the surface, or thick, dark surface, then gleying.
		Drainage Class	Moderately well drained.	Imperfectly, somewhat poorly, or poorly drained.

Table 3 (continued)

Feature	Item	Condition	Conditional Situations	Unfavorable Situations
Performance	Sewage Disposal	Effluent Trans-mission	Less than 1/5 of systems failing; some rank lawn in fields, but no effluent or odor; fails only rarely.	More than 1/5 of systems failing; much rank lawn in fields with effluent or odor; fails periodically.
		Effluent Seepage*	No effluent or odor, but slight staining of curbs, gutters, and walks; fails very occasionally.	Staining of concrete works severe; seepage downslope with effluent or odor; periodic failure.
	Vegetation	Natural	Trees stunted or very thickened at base, foliage and grasses yellowed.	Hydrophytic species such as swamp grass and sedges common.
		Cultivated	Row crops stunted or yellowed; alfalfa stand very poor or discontinuous after first year.	Row crops, except rice, cannot be grown at all; standing water disallows spring plowing.
	Special Problems	Mechanical Behavior	Some difficulty with excavation and placement; forms hard clods when disturbed and dried.	Great difficulty with excavation and placement; very hard or dense, tough or cemented.
		Performance of Structures	Walks readily break up or heave; roads do not perform well; structures show settlement or cracks.	Roads readily break up and heave, concrete works deteriorate very rapidly; structures crack badly.

* Seepage here refers to flow through the soil out of the disposal field prior to adequate biologic rendering.

bedrock, such as contorted and veined crystalline rock or irregularly stratified and folded sedimentary rock, may yield highly variable depths to bedrock and irregular slopes. This in turn may result in a patchwork of colluvial positions and seepage spots. Such irregularity of topography and soil conditions is associated also with limestone bedrock. Some sedimentary deposits consisting of unconsolidated materials may change rapidly and irregularly across the land surface yielding markedly different soil profiles in close proximity to one another. This is quite common where transported materials lie adjacent to residual soils, but it is not unheard of in such broad areas of transported soils as in the Atlantic Coastal Plain and on large river terraces. One might expect old fluvium, including decayed mountain footslope debris and relic stream channel fill, often to yield geographically heterogeneous soils. Glaciated regions, especially near moraines and in highlands, are marked by a heterogeneity of soil materials. Indeed, heterogeneous conditions are so common it is often impractical to be guided by the least suitable soil in a complex and thus condemn large areas for absorption field sewage disposal.

The answer to the problem of how best to utilize such soils for individual sewage disposal systems is simply proper location of the system. However easy this sounds, it is difficult and expensive in practice. In some cases, a profusion of percolation tests have been run so as to delineate approximately such small areas of pervious soil as may occur. However, the percolation test results vary with testing technique and the season of the year so that they cannot always be considered entirely reliable. Also, the procedure of running a large number of tests, more or less at random, is time consuming and costly. A far more satisfactory approach is to have areas of favorable and unfavorable soil delineated on a plot plan on the basis of the criteria set forth above. Many small auger borings may be made and the soil from each judged as satisfactory or unsatisfactory for sewage disposal. After several such borings, lines may be sketched on a large scale plot plan as boundaries between suited and unsuited soil areas. Usually these boundaries can be placed with reference to minor changes in topography, color of the surface soil, and other subtle features. This procedure is similar to that applied to broader areas and smaller scale maps by soil scientists experienced in field work. Indeed, the party responsible for proper location of the disposal system in question may find such scientists available as consultants. Doubtlessly, over the long term, the time and money thus spent would be more efficiently utilized than that devoted to the percolation test.

There are obstacles to the use of field soil scientists in areas of geographically heterogeneous soils. Because of their experience, they can be expected quickly and expertly to delineate soil boundaries,

but they cannot be expected to have had experience in sanitary engineering. Hence, each soil area delineated by them must be finally adjudged by an approved test or responsible official. Nevertheless, the time and testing saved by having the soil areas plotted on a large-scale plan is considerable. A more important barrier to the use of field soil scientists is they are not well known. They are usually unlicensed for professional work and unknown to land developers and engineers who might require their services. Also, many are public employees unavailable for consulting work. Still, those that are competent and available represent an untapped resource of great potential value.

Soils with heterogeneous profiles

A heterogeneous soil profile is one wherein soil character changes markedly with depth from the surface of the land. Soils with heterogeneous profiles are conditional when the workability of an absorption field disposal system depends on the position of the absorption trench in the vertical profile. Because of the nature of pedologic soil-forming processes, it is common to find layers with reduced percolation capacity extending from about one to about four feet from the ground surface. Where a system depends on effluent percolation within such a layer, it generally fails. However, if the first twelve or so inches of soil is preserved in more or less its natural state during construction of the system, and if this topsoil is especially absorptive and permeable, the system may seem to be functioning properly. Also, if the layer with low permeability is completely penetrated during construction so that the system may discharge into absorptive and permeable soil beneath, failure may not occur. Each of these cases represents individual problems not generally considered in present-day design criteria.

Basically, the design of individual sewage disposal systems of the absorption field types allows for effluent to be modified biologically and, theoretically, for discharging fluid downward, laterally, or upward. If the discharging fluid does not reach a potential or existing water supply or break out onto the surface, it may be said that the system is functioning properly. Proper functioning in this manner is thought to be inhibited where the discharge fluid is barred by soil conditions from reaching zones of aeration near the surface of the soil. The upward movement of at least partially modified effluent, possibly by capillarity or as a vapor, and the subsequent evaporation of this fluid from the surface soil, in combination with absorption of fluid by plant roots, are thought to contribute materially to the riddance of effluent. Also, it is considered that biological modification is greatly enhanced near the surface of soil where atmospheric

oxygen is more plentiful than below and where rejuvenation of soil gases with oxygen occurs most readily. Therefore, it is often stipulated that although soil may be especially absorbent with depth, absorption field trenches should not be installed below thirty-six inches from the surface of the ground. Such a requirement, based on the uncertain roles played by evaporation, plant-root absorption, and biological modification near the surface of the ground, often preclude the placement of tile lines below a relatively impermeable layer. However, shallow placement helps insure against ground water contamination since the amount of effluent modification that can be expected deep within a soil is also uncertain.

Clearly, if the problem of conditional soils with heterogeneous profiles is to be resolved, two situtations need to be studied carefully: 1) the biological modification of effluent near the surface of the ground and 2) the modification of effluent at depth in soil with favorable geologic, hydrologic, and topographic positions. The first problem may be approached as though the surface soil were behaving like a seepage bed. Then its required thickness, areal extent, character, position, and vegetation must be evaluated together with various possible absorption field designs to ascertain what, if any, combinations of these will result in workable disposal systems. Although experiences with shallow bedrock situations are analogous and suggest that a shallow layer of soil is always inadequate for a disposal field, the possible benefits of a shallow-field design are great. The second problem, the discharge of effluent deep within a soil, becomes a problem in ground water contamination. There are many unevaluated factors that contribute to the purification of effluent at depth. Obviously, the permeability, absorbency or exchange capacity, gradation, and degree of saturation of the soil are important. These conditions might be optimum in certain decayed crystalline rocks. Again, there is hope that for certain soils great benefits can be realized with seepage-pit types of installations.

The problem of sewage disposal in heterogeneous soil profiles demands research in disposal system design versus effluent modification versus soil parameters. But such research can be beneficial only if provision is made for practical application of the results. This may require the attention of health officials and the use of soil scientists as outlined above.

Soils with relatively homogeneous profiles

Soils with relatively homogeneous profiles, that is, little change in character with depth from the surface, are conditional when their position is favorable and their profile characteristics are marginal for absorption field sewage disposal. Such soil may be SM, SC, or

moderately well drained CL and ML. In many places well drained ML, CL, or even MH soils may have a natural perviousness due to pedologic structure. Such soils are common in the southeastern United States. Conditional soils are often encountered with glacial till or ground moraine where the material tends to consist of large particle sizes.

Conditional soils with relatively homogeneous profiles fall into two categories, those with pronounced pedologic structure and those without. Those without pronounced pedologic structure are unlikely to change greatly in percolation capacity during installation of the disposal system. Methods for absorption field design that equate design absorption area with percolation test results may be more valid for this type of soil than for any other. Further advances in the economical use of such soil must await advances in the design of disposal systems, including the septic tank and dosing apparatus. This is not necessarily the case for soils with pronounced pedologic structure.

Undisturbed soils with pronounced pedologic structure may have a relatively high natural permeability. Destruction of this structure or smearing of the soil surface through which fluid is expected to percolate may cause a permeability reduction on the order of a thousandfold. ML or CL soil may be rendered virtually impervious by remoulding at a particular water content. Certain precautions can be taken against such remoulding during excavation for percolation testing. Thus, such a test may be made to show favorable results. But these same precautions are not necessarily applied during installation of the absorption field system.

For conditional soils with pronounced pedologic structure, there is some evidence that installation techniques may be applied that will result in a working system. What these techniques are, how they can be defined and specified, and to which soils they need to be applied must be determined through research. The importance of this research can be realized when it is known that conditional soils of this type are widespread throughout a region in the United States bounded by the Atlantic Coastal Plain to the east and south and to the north and west by the Wisconsin terminal moraine and Appalachian Mountains. The soils in this region that are conditional for use with individual sewage disposal systems represent a natural resource of great value which, if not used correctly, should not be used at all.

PART IV: RATING SOILS USING PEDOLOGICAL SOIL SURVEY REPORTS AND MAPS

Pedological soil survey reports and maps contain a wealth of information pertinent to individual sewage disposal systems and should be studied with patience. They contain details of the position and profile characteristics of each mapping unit including, in many recent reports, engineering properties of the most important units. The careful study of high quality reports will allow one to judge geology, hydrology, topography, texture and consistency, structure, drainage condition, and vegetation conditions with accuracy. On the basis of these, it may be possible to rate properly a large proportion of the soils in a county relative to residential sewage disposal as well as for other engineering purposes.

Soil survey maps and reports are produced by the United States Department of Agriculture in cooperation with state colleges and agricultural experiment stations in a continuing program of progressive mapping and study of soils. Since the inception of the program more than sixty years ago, about 40 percent of the United States has been mapped. About 50 percent of the eastern portion of the country has been mapped. Most of the mapping has been on a county-by-county basis. More than 1800 counties or areas are completed; 500 to 800 of these are modern, up-to-date reports and maps. Although in the past much of this work was intended for agricultural use, suburban and rural areas have not been excluded from the program. Indeed, because of the great practical value of high quality soils maps for suburban planning and engineering uses, increasing emphasis is being placed on their production.

The Relative Quality of Surveys

The quality of pedological surveys has progressively improved, particularly regarding mapping techniques and classification. Consequently, the quality of the published maps and reports conforms to their chronology in a general way. There are many exceptions to this since quality depends as well on the conduct of the field study which still varies widely among states and agencies.

The Mapping Units of Soils

A soil mapping unit usually bears the name of a taxonomic unit. However, it differs from the defined taxonomic unit by containing a small proportion of "inclusions," other units, up to fifteen percent (7), that cannot be excluded in practical cartography. Fortunately, many recent, high quality maps consist of mapping units containing less

than five percent of such inclusions. The amount of inclusions allowed in a mapping unit may vary among groups of cartographers.

The most general mapping unit is the soil "series." The United States Department of Agriculture Soil Survey Manual describes the series as follows (7. p. 280):

> The soil series is a group of soils having soil horizons similar in differentiating characteristics and arrangement in the soil profile, except for texture of the surface soil, and developed from a particular type of parent material. The soils within a series are essentially homogeneous in all soil profile characteristics except texture, principally of the A or surface horizon, and in such features as slope, stoniness, degree of erosion, topographic position, and depth to bedrock where these features do not modify greatly the kind and arrangement of soil horizons.

The soil series is subdivided into soil "types" on the basis of the texture of the surface soil. Often, the texture of the surface soil reflects important properties of the subsoil. Series names are generally derived from a geographical name. Type names are then formed simply by grouping the name of the pedological textural class of the surface soil with the series name. "Croton" is a series and "Croton silt loam" is a type.

The soil type may be subdivided into phases on the basis of any characteristic or combination of characteristics potentially significant to man's use or management of soils. The basis for subdivision may be slopes, erosion, stoniness and rockiness, soil depth, horizon thickness, drainage, physiography, burning, or silting. Slope, erosion, and stoniness or rockiness are by far the most common phases associated with types. Slope is important to sewage disposal and is expressed in terms similar to those given in Table 1. Erosion has little bearing on sewage disposal except that severely eroded soils may be especially shallow to bedrock or contain many large gullies. Stoniness and rockiness may bear importantly on sewage disposal. When used, these terms are usually defined in the context of the soil survey report. Examples of soil phase are Croton silt loam, level phase, and Legore stony silt loam, hilly shallow phase.

Mapping units that do not bear taxonomic names are usually self-explanatory or are discussed in detail in the soil survey report. Such units include undifferentiated soil groups such as "wet soils" and miscellaneous land types such as beaches, marsh, pits, urban land, and made land. Made land consists of areas artificially filled with soil, trash, or both.

It must be realized that the mapping unit as described in agricultural soil survey reports represents the central concept of the unit, that is, an average of the unit and its variations. Hence, any soils that seem the least questionable for sewage disposal on the basis of soil survey information should be assigned a definite rating only after supplementary field study. Still, it may be possible to assign definite ratings to a large number of soil series, especially the unfavorable ones, on the basis of the soil survey information alone.

The Application of Reports and Maps

Although soil survey information is especially valuable for judging soil suitability for absorption fields, it is not as applicable to seepage pit installations. Mapping units are based on soil profile characteristics that do not always reflect soil conditions many feet below the ground surface. A case in point is where transported soil of low permeability is thin over highly permeable residuum. This mapping unit is established on the basis of the character of the transported material and may give no definition of its thickness. If the soil of low permeability is only three feet thick, absorption fields would not work but seepage pits may. Hence, absorption field ratings cannot be applied to seepage pits.

APPENDIX A: EVALUATION OF SOIL SURVEY MAPPING UNITS IN NORFOLK COUNTY, VIRGINIA FOR URBAN DEVELOPMENT

Field work for the soil survey of Norfolk County, Virginia, was completed by Elvin F. Henry, James Chudoba, and Hobart C. Porter in 1953, and the report and maps were published in 1958. The work is of high quality and in detail.

Norfolk County lies within the Atlantic Coastal Plain. Most of the soils occur on two marine terraces, the Dismal Swamp and the Princess Anne. The Princess Anne terrace has elevations up to 15 feet above sea level. The Dismal Swamp terrace, the higher of the two, rises to elevations of 15 to 25 feet. About 1/5 of the county is in the Dismal Swamp proper.

The county is nearly level with an overall drainage pattern that is not well established. There are many small streams bordered by low ridges, 100 to 600 feet wide, containing soils classed as well-drained. Many of the ridges rise sharply to broad flat plains occupied chiefly by soils classed as poorly drained.

Three features dominate the nature of soils in Norfolk County: the subsurface hydrology, the size of the constituent mineral particles, and the presence of organic matter. In some places, such as in the Dismal Swamp, the water table is at the surface of the soil throughout the year and accumulations of organic matter occur. In other places, the water table lies at the surface of the soil during wet seasons only and organic soil is not abundant. In still other places, the water table seldom lies closer than a few feet from the surface of the soil and little organic matter occurs. Superimposed on these hydrologic conditions are wide variations in soil-material character. Mapping units vary from soils that are essentially clean sands to soils that have high plasticity. There is some variation within a mapping unit, especially when one considers the vertical dimension of the soil except for the uppermost few feet of that soil. These variations are generally minor relative to the differences among units. A categorization of the mapping units according to soil features of interest to engineers appears in Table A1.

Most of the soil in Norfolk County is unsuited for individual sewage disposal systems because of a seasonally high water table, low permeability, or both. Ratings of the soil survey mapping units for disposal systems of the absorption field type are given in Table A2. There are few cases where high water table does not preclude the satisfactory use of seepage pit installations.

Table A 1

Classification of Soil Survey Mapping Units

According to Features of Interest to Engineers

Features of Interest to Engineers	Soil Series or Mapping Unit
Soil mapping units predominantly coarse-grained, with few or no fines in uppermost few feet of soil.	Coastal beach Dragston Fallsington Galestown Klej Pocomoke Sassafras Woodstown
Soil mapping units low to moderate in plasticity throughout, or in one or more layers in the uppermost few feet.	Bertie Matapeake Matapex Pasquotank Portsmouth Mixed alluvial land Othello Weeksville Wet soils
Soil mapping units moderate to high in plasticity throughout, or in one or more layers in the uppermost few feet.	Bayboro Bladen Keyport Lenoir Elkton
Soil miscellaneous mapping units consist of tidal marsh, or are highly organic throughout, or in uppermost few feet.	Mucky peat Tidal Marsh
Unclassified	Made land Pits Urban and farmsteads

Table A 2

Rating of Soil Survey Mapping Units, Norfolk County, Virginia, for Absorption Field Sewage Disposal Systems

Mapping Unit	Rating	Remarks
Bayboro, all types	Unfavorable	High water table.
Bertie, all types	Unfavorable	Seasonally high water table.
Bladen silt loam	Unfavorable	Low permeability.
Coastal beach	Unfavorable	Subject to flooding.
Dragston, all types	Unfavorable	Seasonally high water table.
Elkton, all types	Unfavorable	Low permeability.
Fallsington fine sandy loam	Unfavorable	Seasonally high water table.
Galestown loamy fine sand	Favorable	
Keyport very fine sandy loam	Unfavorable	Low permeability.
Klej loamy fine sand	Conditional	Moderately high water table.
Lenoir very fine sandy loam	Unfavorable	Low permeability.
Made land	Unclassified	
Matapeake fine sandy loam, all phases	Favorable	
Mattapex very fine sandy loam, all phases	Conditional	Moderate permeability.
Mixed alluvial land	Unfavorable	Subject to flooding.
Mucky peat, all phases	Unfavorable	High water table.
Othello, all types and phases	Unfavorable	High water table.

Table A 2 (continued)

Mapping Unit	Rating	Remarks
Pasquotank very fine sandy loam	Unfavorable	High water table.
Pocomoke fine sandy loam	Unfavorable	High water table.
Portsmouth, all types	Unfavorable	High water table.
Sassafras, all types and phases	Favorable	
Tidal Marsh	Unfavorable	Subject to flooding.
Weeksville silt loam	Unfavorable	High water table.
Wet soils	Unfavorable	High water table.
Woodstown fine sandy loam	Conditional	Moderately high water table.
Woodstown loamy fine sand	Favorable	
Pits	Unclassified	
Urban and farmsteads	Unclassified	

APPENDIX B: EVALUATION OF SOIL SURVEY MAPPING UNITS IN LOUDOUN COUNTY, VIRGINIA, FOR URBAN DEVELOPMENT

Field work for the soil survey of Loudoun County, Virginia, was completed by H. C. Porter and associates in 1950 and the reports and maps published in 1960. The work is in detail and of the highest quality. The report contains sections on the engineering properties of the mapping units and rates several of these units on their suitability for septic tank drainage systems. These ratings are not based on Federal Housing Administration standards and do not agree entirely with those given in Table B 1.

Nearly half of Loudoun County is suitable for absorption field disposal systems, nearly half is unfavorable for this purpose, and a small percentage is of questionable suitability. Much of the unfavorable soil lies in steep, rough, or rocky land with soil shallow to bedrock. Some lies along the Potomac River or smaller waterways or in natural drainageways where periodic flooding or seasonally high water table precludes the satisfactory use of individual sewage disposal systems. Areas of relatively impervious soil occur in the eastern portion of the county where the terrain is undulating and rolling and the bedrock is diabase. The eastern part of the county also contains extensive areas of silty soil shallow to Triassic shale bedrock. Most such soil is unsuitable for absorption fields.

In some places, especially in the western portion of the county, the soil is unfavorable for absorption fields because of a compacted layer with low permeability or soil material with high plasticity. Where these conditions occur only in the uppermost few feet of soil and where the soil is highly permeable below, seepage pit installations may give satisfactory performance. Old colluvium, for instance, is sometimes shallow over residual soil with high permeability. These special geologic situations are not indicated on the agricultural soil survey maps. Mapping units not rated favorable for absorption field sewage disposal, which may contain soil satisfactory for seepage pits and should be rated conditional for that purpose, are included in the Belvoir, Dyke, Elk, Hiwassee, Masada, Thurmont, and Unison Series.

The Loudoun County mapping units were classified also according to features of interest to engineers as given in Table B 2. About 35 percent of the county remains unclassified for this purpose. The unclassified areas include soils that are generally highly variable in depth to bedrock or have an average depth of between 3 and 6 feet, are low to moderate in plasticity, and are residual. Still, one should not suppose that all this unclassified soil does not have in at least a few places some of the features of the classified soil.

Table B 1

Rating of Soil Survey Mapping Units, Loudoun County, Virginia

for Absorption Field Sewage Disposal Systems

Mapping Unit	Rating	Remarks
Airmont stony loam, undulating and rolling phases	Conditional	Moderately shallow to bedrock.
Airmont stony loam, hilly phase	Unfavorable	Shallow to bedrock.
Athol gravelly silt loam and silt loam, all phases	Favorable	
Athol rocky silt loam, all phases	Conditional	Bedrock 15-40% of the surface.
Athol very rocky silt loam, all phases	Unfavorable	Bedrock more than 40% of surface.
Belvoir loam	Unfavorable	Low permeability.
Bermudian silt loam	Unfavorable	Subject to flooding.
Bowmansville silt loam	Unfavorable	Subject to flooding.
Braddock, all types and phases	Favorable	
Brandywine loam and silt loam, rolling phases	Favorable	
Brandywine loam and silt loam, hilly and eroded hilly phases	Conditional	Moderately shallow to bedrock.
Brandywine loam and silt loam, steep phases	Unfavorable	Steep and shallow to bedrock.
Brandywine sandy loam, rolling phase	Conditional	Moderately shallow to bedrock.
Brandywine sandy loam, hilly and steep phases	Unfavorable	Steep and shallow to bedrock.

Table B 1 (continued)

Mapping Unit	Rating	Remarks
Brandywine stony loam, rolling phase	Conditional	Moderately shallow to bedrock.
Brandywine stony loam, hilly, eroded hilly, and steep phases	Unfavorable	Shallow to bedrock.
Brandywine stony sandy loam, all phases	Unfavorable	Shallow to bedrock.
Brecknock gravelly silt loam, all phases	Unfavorable	Low permeability.
Buckingham stony fine sandy loam, all phases	Unfavorable	Shallow to bedrock.
Bucks, all types and phases	Favorable	
Calverton silt loam, all phases	Unfavorable	Low permeability.
Captina silt loam, all phases	Unfavorable	Low permeability.
Catlett, all types and phases	Unfavorable	Shallow to bedrock.
Catoctin, all types and phases	Unfavorable	Shallow to bedrock.
Chester, all types and phases	Favorable	
Chester-Brandywine, all types and phases	Favorable	
Chewacla silt loam	Unfavorable	Subject to flooding.
Clifton stony silt loam, all phases	Favorable	
Congaree, all types	Unfavorable	Subject to flooding.
Croton silt loam, all phases	Unfavorable	Low permeability.
Dyke cobbly silty clay loam, all phases	Conditional	Moderate permeability.

Table B 1 (continued)

Mapping Unit	Rating	Remarks
Elbert, all types and phases	Unfavorable	Low permeability.
Elioak silt loam, all phases	Favorable	
Elk loam	Conditional	Moderate permeability.
Emory silt loam	Unfavorable	Seasonally high water table.
Eubanks-Chester loams and silt loams, all phases	Favorable	
Eubanks-Chester stony loams and silt loams, undulating and rolling phases	Favorable	
Eubanks-Chester stony loams and silt loams, hilly phases	Unfavorable	Shallow to bedrock.
Fauquier silt loam, undulating and rolling phases	Favorable	
Fauquier silt loam, hilly phase	Conditional	Moderately shallow to bedrock.
Fauquier silty clay loam, undulating and rolling phases	Favorable	
Fauquier silty clay loam, hilly phases	Conditional	Moderately shallow to bedrock.
Fauquier stony silt loam, rolling phase	Favorable	
Fauquier stony silt loam, hilly phase	Conditional	Moderately shallow to bedrock.
Glenelg silt loam, all phases	Favorable	
Hazel silt loam, all phases	Unfavorable	Shallow to bedrock.
Hiwassee, all types and phases	Conditional	Moderately permeable.

Table B 1 (continued)

Mapping Unit	Rating	Remarks
Huntington silt loam	Unfavorable	Subject to flooding.
Iredell-Mecklenburg, all types and phases	Unfavorable	Low permeability.
Kelly silt loam, all phases	Unfavorable	Low permeability.
Legore, all types and phases	Unfavorable	Shallow to bedrock.
Lindside silt loam	Unfavorable	Subject to flooding.
Manassas silt loam	Unfavorable	Seasonally high water table.
Manor silt loam, rolling and hilly phases	Favorable	
Manor silt loam, steep phase	Unfavorable	Steep slopes.
Masada, all types and phases	Unfavorable	Low permeability.
Meadowville, all types	Unfavorable	Seasonally high water table.
Melvin silt loam	Unfavorable	Subject to flooding.
Mixed alluvial land	Unfavorable	Subject to flooding.
Montalto, all types and phases	Favorable	
Myersville silt loam, undulating and rolling phases	Favorable	
Myersville silt loam, hilly phases	Conditional	Moderately shallow to bedrock.
Myersville stony silt loam, undulating and rolling phases	Favorable	
Myersville stony silt loam, steep phases	Unfavorable	Shallow to bedrock.

Table B 1 (continued)

Mapping Unit	Rating	Remarks
Penn cobbly silt loam, undulating phase	Favorable	
Penn cobbly silt loam, rolling phase	Conditional	Moderately shallow to bedrock.
Penn loam, undulating phase	Favorable	
Penn loam, rolling phase	Conditional	Moderately shallow to bedrock.
Penn loam, hilly phase	Unfavorable	Shallow to bedrock.
Penn shaly silt loam, all phases	Unfavorable	Shallow to bedrock.
Penn silt loam, undulating phases	Favorable	
Penn silt loam, rolling phases	Conditional	Moderately shallow to bedrock.
Penn silt loam, hilly phase	Unfavorable	Shallow to bedrock.
Penn stony silt loam, all phases	Unfavorable	Shallow to bedrock.
Readington silt loam, undulating phase	Unfavorable	Low permeability.
Robertsville silt loam	Unfavorable	Low permeability.
Rocky land, rolling acidic rock phase	Conditional	Moderately shallow to bedrock.
Rocky land, rolling basic rock phase and hilly phases	Unfavorable	Shallow to bedrock.
Very rocky land, all phases	Unfavorable	Shallow to bedrock.
Rohrersville, all types	Unfavorable	Seasonally high water table.
Rowland silt loam	Unfavorable	Subject to flooding.

Table B 1 (continued)

Mapping Unit	Rating	Remarks
Sequatchie loam	Favorable	
Stony colluvial land, all phases	Unfavorable	Seasonally high water table.
Thurmont, all types and phases	Unfavorable	Low permeability.
Trego gravelly silt loam	Unfavorable	Low permeability.
Unison, all types and phases	Unfavorable	Low permeability.
Wehadkee silt loam	Unfavorable	High water table.
Whiteford silt loam, undulating phase	Favorable	
Whiteford silt loam, rolling phase	Conditional	Moderately shallow to bedrock.
Whiteford silt loam, hilly shallow phase	Unfavorable	Shallow to bedrock.
Whiteford stony silt loam, all phases	Unfavorable	Shallow to bedrock.
Wickham loam	Favorable	
Worsham silt loam	Unfavorable	High water table.
Made land	Unclassified	

Table B 2

Classification of Soil Survey Mapping Units, Loudoun County, Virginia,

According to Features of Interest to Engineers

Features of Interest to Engineers	Mapping Unit
Bedrock or large boulders common at less than 3 feet beneath soil surface.	Airmont stony loam, all phases
	Athol rocky silt loam, all phases
	Athol very rocky silt loam, all phases
	Buckingham stony fine sandy loam, all phases
	Catlett, all types and phases
	Catoctin, all types and phases
	Hazel silt loam, all phases
	Legore, all types and phases
	Penn loam, hilly phase
	Penn shaly silt loam, all phases
	Penn silt loam, hilly phase
	Penn stony silt loam, all phases
	Readington silt loam, undulating phase
	Rocky land, all phases
	Very rocky land, all phases
	Stony colluvial land, all phases
	Whiteford silt loam, hilly shallow phase

Table B 2 (continued)

Features of Interest to Engineers	Mapping Unit
	Whiteford stony silt loam, all phases
Bedrock or large boulders rare at less than 6 feet beneath the soil surface.	Belvoir loam
	Braddock, all types and phases
	Captina silt loam, all phases
	Chester, all types and phases
	Clifton stony silt loam, all phases
	Dyke cobbly silty clay loam, all phases
	Elioak silt loam, all phases
	Elk loam
	Eubanks-Chester loams and silt loam all phases
	Glenelg silt loam, all phases
	Hiwassee, all types and phases
	Manor silt loam, all phases
	Masada, all types and phases
	Robertsville silt loam
	Sequatchie loam
	Thurmont, all types and phases
	Trego gravelly silt loam
	Unison, all types and phases

Table B 2 (continued)

Features of Interest to Engineers	Mapping Unit
	Wickham loam
Soils with high plasticity.	Elbert, all types and phases
	Iredell-Mecklenburg, all types and phases
	Kelly silt loam, all phases
Soils derived from local colluvium at least in part.	Emory silt loam
	Manassas silt loam
	Meadowville, all types and variants
	Rohrersville, all types
	Worsham silt loam
Soils subject to periodic flooding by permanent streams	Bermudian silt loam
	Bowmansville silt loam
	Chewacla silt loam
	Congaree, all types
	Huntington silt loam
	Lindside silt loam
	Melvin silt loam
	Mixed alluvial land
	Rowland silt loam
	Wedhadkee silt loam

APPENDIX C: EVALUATION OF SOIL SURVEY MAPPING UNITS IN FULTON COUNTY, GEORGIA, FOR URBAN DEVELOPMENT

Fulton County, Georgia, lies entirely within the Piedmont Section of the Older Appalachians Province. Accordingly, its soils are characteristic of those found in much of the Southern Piedmont, which commonly has red, clayey subsoil materials near the surface of the land. The Soil Survey Report of Fulton County, Georgia, lists these soils as those of the uplands of the Atlantic Plateau and shows that they constitute a major portion of the county. Other materials in Fulton County are soils of colluvial slopes, soils of stream terraces, and soils of first bottoms.

With regard to absorption field sewage disposal, the soils of colluvial slopes and those of first bottoms in Fulton County are unfavorable because they are subject to periodic flooding, ground water seepage, or both. Except for the Molena, Wickham, and Hiwassee series, the soils of the stream terraces exhibit a generally unfavorable drainage condition for absorption fields. The Molena and Wickham series are rated as favorable, but Hiwassee soil is considered conditional because of its deep, clayey profile and the incidence of failing systems in similar soil further north. Not unlike the Hiwassee soil is much of the soil of the uplands. The Cecil, Appling, Lloyd, Lockhart, and Davidson series are all rated conditional on the basis of their profile characteristics and evidence that numerous, though not all, systems installed in such material do not give satisfactory performance. Places where absorption field disposal systems are functioning satisfactorily in such soil can be found. These successes may be the result of refinements in construction techniques, installation of the trenches to depths below the lower limit of the soil layer containing a high percentage of clay (as might be practical in the cases of certain occurrences of Cecil, Appling, Lockhart, and Lloyd soils), or insufficient time since installation for failure to be manifest. As implied by the limited depth (3 to 6 feet below the surface) of the clayey subsoil material associated with much of the upland soils, seepage pit installations might prove satisfactory where groundwater contamination is not a serious problem. Other soils rated as conditional for absorption fields include those with favorable profile properties which are located on steep (15-25 per cent) slopes. Where the soils with conditional profile characteristics occur on steep slopes, they are given an unfavorable rating. It has been observed that in such situations disposal system failures are common. Other unfavorable situations in the uplands are where the soil is shallow to bedrock, as in the case

of the Louisburg series, or is relatively impervious and tends to be waterlogged, as in the case of the Iredell, Mecklenburg, and Helena series. Table C 1 summarizes the rating of soil survey mapping units in Fulton County, Georgia, for absorption field sewage disposal systems.

A classification of the Fulton County mapping units according to general features of interest to engineers is given in Table C 2. The various classes are not mutually exclusive such that colluvium, for example, may also be deep to bedrock or large boulders. However, an attempt is made to recognize the most distinctive single feature of each unit pertinent to residential housing such that colluvium, for example, is distinguished by its geologic origin and implied hydrologic position rather than depth. Less than 10 per cent of the county remains unclassified as to general features. Most of this was mapped as unclassified city land, made land, or gullied land. The remainder, the Louisa series and Hiwassee-Louisa complex, is mostly residual soil with low plasticity and high variability in depth to bedrock or large boulders.

Table C 1

Rating of Soil Survey Mapping Units, Fulton County, Georgia, for Absorption Field Sewage Disposal Systems

Mapping Unit	Rating	Remarks
Altavista, all types and phases	Unfavorable	Seasonally high water table.
Appling sandy clay loam, all phases	Conditional	Moderate permeability.
Appling sandy loam, undulating, rolling, and hilly phases	Conditional	Moderate permeability.
Appling sandy loam, steep phase	Unfavorable	Moderate permeability and steep slopes.
Augusta fine sandy loam	Unfavorable	Seasonally high water table.
Buncombe loamy fine sand	Unfavorable	Subject to flooding.
Cecil clay loam and sandy loam, undulating, rolling, and hilly phases	Conditional	Moderate permeability.
Cecil clay loam and sandy loam, steep phase	Unfavorable	Moderate permeability and steep slopes.
Chewacla, all types	Unfavorable	Subject to flooding.
Congaree, all types	Unfavorable	Subject to flooding.
Davidson clay loam, all phases	Conditional	Moderate permeability.
Grover fine sandy loam, all phases	Favorable	
Gullied land	Unclassified	
Helena sandy loam	Unfavorable	Low permeability.

Table C 1 (continued)

Mapping Unit	Rating	Remarks
Hiwassee-Louisa soil	Conditional	Moderate permeability.
Hiwassee sandy loam, all phases	Conditional	Moderate permeability.
Iredell stony clay loam	Unfavorable	Low permeability.
Lloyd clay loam and sandy loam, undulating, rolling, and hilly phases	Conditional	Moderate permeability.
Lloyd gravelly sandy loam, clay loam, and sandy loam, steep phase	Unfavorable	Moderate permeability and steep slopes.
Lockhart-Cecil clay loams and sandy loams, undulating, rolling, and hilly phases	Conditional	Moderate permeability.
Lockhart-Cecil clay loams and sandy loams, steep phases	Unfavorable	Moderate permeability and steep slopes.
Louisa fine sandy loam, rolling and hilly phases	Favorable	
Louisa fine sandy loam, steep phase	Conditional	Steep slopes.
Louisburg sandy loam, all phases	Unfavorable	Shallow to bedrock.
Made land	Unclassified	
Madison clay loam, fine sandy loam, and gravelly sandy loam, undulating, rolling, and hilly phases	Favorable	
Madison fine sandy loam, steep phase	Conditional	Steep slopes.

Table C 1 (continued)

Mapping Unit	Rating	Remarks
Madison-Grover-Louisa gravelly clay loams and gravelly sandy loams, hilly phases	Favorable	
Madison-Grover-Louisa gravelly sandy loams, steep phases	Conditional	Steep slopes.
Mechlenburg, all types and phases	Unfavorable	Low permeability.
Mixed alluvium, all drainage conditions	Unfavorable	Subject to flooding.
Molena loamy sand	Favorable	
Riverwash	Unfavorable	Subject to flooding.
Seneca fine sandy loam, all phases	Unfavorable	Seasonally high water table.
Starr loam, all phases	Unfavorable	Seasonally high water table.
Stony land, all phases	Unfavorable	Shallow to bedrock.
Unclassified city land	Unclassified	
Wehadkee, all types	Unfavorable	Subject to flooding.
Wickham fine sandy loam, all phases	Favorable	
Worsham sandy loam, all phases	Unfavorable	Seasonally high water table.

Table C 2

Classification of Scil Survey Mapping Units, Fulton County, Georgia,

According to Features of Interest to Engineers

Features of Interest to Engineers	Mapping Unit
Bedrock or large boulders common at less than 3 feet beneath the soil surface.	Louisburg sandy loam, all phases
	Stony land, rolling, hilly, and steep
Bedrock or large boulders rare at less than 6 feet beneath the soil surface.	Altavista fine sandy loam, all phases
	Appling, all types and phases
	Augusta fine sandy loam
	Cecil, all types and phases
	Davidson clay loam, all phases
	Grover fine sandy loam, all phases
	Hiwassee sandy loam, all phases
	Lloyd, all types and phases
	Lockhart-Cecil, all types and phases
	Madison, all types and phases
	Madison-Grover-Louisa, all types and phases
	Molena loamy sand, all phases
	Wickham fine sandy loam, all phases

Table C 2 (continued)

Features of Interest to Engineers	Mapping Unit
Soils with high plasticity.	Helena sandy loam, eroded rolling phase
	Iredell stony loam, rolling phase
	Mechlenburg, all types and phases
Soils derived from local colluvium at least in part.	Seneca fine sandy loam, all phases
	Starr loam, all phases
	Worsham sandy loam, all phases
Soils subject to periodic flooding by permanent streams.	Buncombe loamy fine sand
	Chewacla, all types
	Congaree, all types
	Mixed alluvium
	Riverwash
	Wehadkee, all types

APPENDIX D: EVALUATION OF SOIL SURVEY MAPPING UNITS IN KNOX COUNTY, TENNESSEE, FOR URBAN DEVELOPMENT

Knox County lies within the Tennessee Valley Section of the Newer Appalachians Province. It is marked by rugged ridges of interbedded sandstone and shale and calcareous sandstone as well as extensive valleys of soft shale and argillaceous limestone. In addition, there are broad areas of cherty dolomitic limestone. The soils associated with these materials may be grouped into soils on uplands, those on stream terraces, and those on first bottoms.

In regard to sewage disposal by individual absorption field systems, soils on first bottoms must be rated as unfavorable because of the hazard of flooding. In some places, flooding can be expected to be less frequent than in the recent past because of the construction of flood-control dams on major rivers in the county, but it would be presumptive to assume that flooding has been entirely eliminated as a problem for any soil series located on first bottoms. However, soils on the stream terraces, including those on low stream terraces, are free from flooding. Of these, the Etowah, Nolichucky, Sequatchie, and Waynesbore soil series are rated as favorable for absorption field sewage disposal systems. Two other series, Wolftever and Tyler are rated as unfavorable on the basis of their tendency to be waterlogged at least seasonally and a third series, Cumberland, is rated as conditional because of the high clay content of the soil profile and a questionable performance history. Of the soils on foot slopes and along drains, all are rated as unfavorable except the Alcoa series, which consists of pervious materials and is located on relatively high foot slopes below ridges of sandy soil. In most instances, the favorable rating is due to the poor hydrologic position of the soils. In the case of the Jefferson soil, whose hydrologic position is favorable, the unfavorable rating is based on the generally shallow depth to bedrock of the soil material as it is mapped in Knox County. Many of the soils of the uplands are rated as unfavorable because of their shallow depth to bedrock. Others consist of materials with low permeability, as in the case of the Colbert soil, or on slopes in excess of 25 per cent. Only the Tellico series is rated as favorable. A large group of soils, including the Dewey, Decatur, Fullerton, Clarksville, and Bolton Series, are rated as conditional because of their large silt and clay content and questionable performance record. Along with the Cumberland soil, one might expect them to be favorable for sewage disposal on the basis of an apparent natural permeability, possibly induced by a pronounced "structured"

condition in a pedological sense and the working systems that occasionally may be found in such materials. Still, questionable percolation test results coupled with the incidence of a large number of failures in such soils cause them to be rated as conditional. It is thought that with the current disposal system design and construction practices being used in the area these soils can in no way be considered favorable. Yet, evidence suggests that they are not beyond satisfactory use where proper techniques of design and installation are employed. Such techniques have yet to be defined for these soils. Imposed on the general ratings mentioned are a conditional rating for slopes of 12-25 per cent and an unfavorable rating for slopes in excess of 25 per cent. Table D 1 gives the rating of soil survey mapping units in Knox County for absorption field disposal systems.

In addition, the Knox County mapping units were classified according to features of interest to engineers as given in Table D 2. A primary consideration in this classification is depth to bedrock or large boulders. With respect to the first occurrence below the surface of bedrock or large boulders, hereinafter simply called "depth to rock," five categories were established as follows:

Shallow - for soils with a depth to rock of less than 4 feet.
Moderately shallow - for soils with a depth to rock ranging from 0 to 10 feet.
Moderately deep - for soils with a depth to rock ranging from 4 to greater than 10 feet.
Deep - for soils with a depth to rock of greater than 10 feet.
Highly variable - for soils with a depth to rock ranging from 0 to greater than 10 feet.

The shallow and moderately shallow categories represent situations in which the depth to rock is less than 4 feet and less than 10 feet respectively. For the moderately deep and deep categories, the depth to rock is greater than 4 feet and greater than 10 feet respectively. These categories overlap, but they are established primarily to set limits within which a first occurrence of rock below the surface of a soil might be anticipated.

The depth-to-rock categories were applied to all the soil survey mapping units in Knox County except those interpreted as representing soils subject to periodic flooding by permanent streams. These soils are for the most part moderately deep, as this category is defined above, but their hydrologic position is considered to be the most significant feature of interest to engineers. Hydrologic position also is considered to be of great importance in the case of soils derived from local alluvial or colluvial materials. Accordingly, these soils are categorized as such and their category subdivided according to depth to rock using the above definitions.

Table D 1

Rating of Soil Survey Mapping Units, Knox County, Tennessee, for Absorption Field Sewage Disposal Systems

Mapping Unit	Rating	Remarks
Alcoa silt loam, all phases	Favorable	
Armuchee, all types and phases	Unfavorable	Shallow to bedrock.
Bland, all types and phases	Unfavorable	Shallow to bedrock.
Bolton silt loam and silty clay loam, hilly and rolling phases	Conditional	Moderate permeability.
Bolton silt loam and silty clay loam, steep phase	Unfavorable	Steep slopes.
Camp silt loam	Unfavorable	Seasonally high water table.
Chewacla silt loam	Unfavorable	Subject to flooding.
Clarksville cherty silt loam, rolling and hilly phases	Conditional	Moderate permeability.
Clarksville cherty silt loam, steep phase	Unfavorable	Steep slopes.
Colbert silty clay and silty clay loam	Unfavorable	Low permeability.
Congaree fine sandy loam and silt loam	Unfavorable	Subject to flooding.
Cumberland, all types and phases	Conditional	Moderate permeability.
Dandridge and Litz, all types and phases	Unfavorable	Shallow to bedrock.
Dandridge, all types and phases	Unfavorable	Shallow to bedrock.

Table D 1 (continued)

Mapping Unit	Rating	Remarks
Decatur, all types and phases	Conditional	Moderate permeability.
Dewey, all types, undulating, rolling, and hilly phases	Conditional	Moderate permeability.
Dewey silty clay loam, eroded steep phase	Unfavorable	Steep slopes.
Emory and Abernathy silt loams	Unfavorable	Seasonally high water table.
Emory silt loam, all phases	Unfavorable	Seasonally high water table.
Etowah silt loam and silty clay loam, undulating and rolling phases	Favorable	
Etowah silty clay loam, hilly phases	Conditional	Steep slopes.
Farragut silty clay loam, all phases	Unfavorable	Moderate permeability and shallow to rock.
Fullerton cherty silt loam and cherty silty clay loam, hilly and rolling phases	Conditional	Moderate permeability.
Fullerton cherty silt loam and cherty silty clay loam, steep phases	Unfavorable	Steep slopes.
Fullerton loam, silt loam, and silty clay loam, all phases	Conditional	Moderate permeability.
Greendale, all types and phases	Unfavorable	Seasonally high water table.
Gullied land, all soil materials	Unfavorable	Steep slopes and shallow to rock.
Guthrie silt loam	Unfavorable	Seasonally high water table.
Hamblen, all types	Unfavorable	Subject to flooding.

Table D 1 (continued)

Mapping Unit	Rating	Remarks
Huntington silt loam, all phases	Unfavorable	Subject to flooding.
Jefferson and Montevallo, all types and phases	Unfavorable	Shallow to rock.
Jefferson loam	Unfavorable	Shallow to rock.
Leadvale and Cotaco loams, all phases	Unfavorable	Seasonally high water table.
Leadvale and Whitesburg silt loams all phases	Unfavorable	Seasonally high water table.
Limestone rockland, all phases	Unfavorable	Shallow to rock.
Lindside silt loam	Unfavorable	Subject to flooding.
Melvin silt loam	Unfavorable	Subject to flooding.
Montevallo, all types and phases	Unfavorable	Shallow to rock.
Muskingum-Lehew fine sandy loams, all phases	Unfavorable	Shallow to rock.
Muskingum stony fine sandy loam	Unfavorable	Shallow to rock.
Neubert loam, all phases	Unfavorable	Seasonally high water table.
Nolichucky gravelly loam	Favorable	
Ooltewah silt loam	Unfavorable	Seasonally high water table.
Prader silt loam	Unfavorable	Subject to flooding.
Roane silt loam	Unfavorable	Subject to flooding.

Table D 1 (continued)

Mapping Unit	Rating	Remarks
Sequatchie fine sandy loam	Favorable	
Sequoia, all types and phases	Unfavorable	Shallow to rock.
Staser, all types and phases	Unfavorable	Subject to flooding.
Stony land, all slopes and soil materials	Unfavorable	Shallow to rock.
Talbott silty clay loam, all phases	Unfavorable	Low permeability.
Tellico clay loam, hilly phase	Conditional	Moderately strong relief.
Tellico clay loam, rolling phase	Favorable	
Tellico clay loam, steep phase	Unfavorable	Steep slopes.
Tellico loam, hilly phases	Conditional	Moderately strong relief.
Tellico loam, rolling phase	Favorable	
Tellico loam, steep phases	Unfavorable	Steep slopes.
Tyler silt loam	Unfavorable	Seasonally high water table.
Waynesboro loam and clay loam, hilly phases	Conditional	Moderately strong relief.
Waynesboro loam, undulating and rolling phases	Favorable	
Wolftever silty clay loam, all phases	Unfavorable	Low permeability.

Table D 2

Classification of Soil Survey Mapping Units, Knox County, Tennessee,

According to Features of Interest to Engineers

Features of Interest to Engineers	Mapping Unit
Shallow to rock; bedrock or large boulders common at less than four feet beneath the soil surface.	Armuchee, all types and phases
	Bland, all types and phases
	Colbert, all types and phases
	Dandridge, all types and phases
	Dandridge and Litz, all types and phases
	Farragut, all types and phases
	Gullied land: Armuchee and Litz soil materials
	Gullied land: Sequoia and Montevallo soil materials
	Jefferson and Montevallo, all types and phases
	Limestone rockland, all slopes
	Montevallo, all types and phases
	Muskingum stony fine sandy loam, steep phase
	Muskingum-Lehew fine sandy loam, all phases

Table D 2 (continued)

Features of Interest to Engineers	Mapping Unit
	Sequoia, all types and phases
	Sequoia-Bland silty clay loams, all phases
	Stony land, all slopes and soil materials
Moderately shallow to rock; bedrock or large boulders common at less than ten feet beneath the soil surface.	Alcoa silt loam, eroded rolling phase
	Gullied land: Tellico and Muskingum soil materials
	Talbott silty clay loam, all phases
	Tellico loam, steep phase
	Tellico loam, eroded steep phase
	Tellico clay loam, severely eroded steep phase
Moderately deep to rock; bedrock or large boulders rare at less than four feet beneath the soil surface.	Cumberland silty clay loam, eroded undulating phase
	Cumberland silty clay loam, eroded rolling phase
	Cumberland silty clay loam, severely eroded rolling phase
	Cumberland gravelly fine sandy loam, eroded rolling phase

Table D 2 (continued)

Features of Interest to Engineers	Mapping Unit
	Decatur, all types and phases
	Dewey, all types and phases
	Etowah, all types and phases
	Fullerton cherty silt loam, steep phase
	Fullerton cherty silt loam, eroded steep phase
	Fullerton cherty silty clay loam, severely eroded steep phase
	Nolichucky gravelly loam, eroded rolling phase
	Waynesboro loam, eroded undulating phase
	Waynesboro loam, eroded rolling phase
Deep to rock; bedrock or large boulders rare at less than ten feet beneath the soil surface.	Bolton, all types and phases
	Clarksville cherty silt loam, all phases
	Fullerton silt loam, all phases
	Fullerton silty clay loam, all phases
	Fullerton cherty silt loam, rolling phase
	Fullerton cherty silt loam, eroded rolling phase
	Fullerton cherty silt loam, hilly phase
	Fullerton cherty silt loam, eroded hilly phase

Table D 2 (continued)

Features of Interest to Engineers	Mapping Unit
	Fullerton cherty silty clay loam, severely eroded rolling phase
	Fullerton cherty silty clay loam, severely eroded hilly phase
	Fullerton loam, all phases
	Sequatchie fine sandy loam
	Wolftever silty clay loam, all phases
Soils subject to periodic flooding by permanent streams.	Chewacla silt loam
	Congaree, all types and phases
	Hamblen, all types
	Huntington silt loam, all phases
	Lindside silt loam
	Melvin silt loam
	Prader silt loam
	Roane silt loam
	Staser, all types and phases

Table D 2 (continued)

Features of Interest to Engineers	Mapping Unit
Soils derived from local colluvium at least in part; bedrock or large boulders rare at less than four feet beneath the soil surface.	Emory silt loam, all phases
	Emory and Abernathy silt loams
	Greendale, all types and phases
	Leadvale and Cotaco loams, undulating phases
	Leadvale and Whitesburg silt loams, undulating phases
	Ooltewah silt loam
	Tyler silt loam
Soils derived from local colluvium at least in part; first occurrence of bedrock or large boulders ranges from the surface to greater than ten feet beneath the surface.	Camp silt loam
	Leadvale and Cotaco loams, rolling phases
	Leadvale and Whitesburg silt loams, rolling phases
	Neubert loam, all phases
	Waynesboro loam, eroded hilly phase
	Waynesboro clay loam, severely eroded hilly phase

Table D 2 (continued)

Features of Interest to Engineers	Mapping Unit
Highly variable depth to rock; first occurrence of bedrock or large boulders ranges from the surface to greater than ten feet beneath the surface.	Alcoa silt loam, eroded undulating phase
	Cumberland silty clay loam, eroded hilly phase
	Cumberland silty clay loam, severely eroded hilly phase
	Gullied land: Fullerton and Talbott soil materials
	Gullied land: Talbott and Decatur soil materials
	Jefferson loam, eroded rolling phase
	Made land
	Tellico loam, hilly phase
	Tellico loam, eroded hilly phase
	Tellico clay loam, severely eroded hilly phase
	Tellico loam, rolling phase
	Tellico loam, eroded rolling phase
	Tellico clay loam, severely eroded rolling phase

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